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Journal
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Vol. 188 JULY, 1919 No. 1

A RECTANGULAR-COMPONENT TWO-DIMENSIONAL ALTERNATING-CURRENT POTENTIOMETER.*

BY

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Professor of Electrical Engineering: Harvard University, and the Massachusetts Institute of Technology, Member of the Institute.

AND

EDY VELANDER, A.M.

It is here proposed to describe the construction, mode of operation, and use of a special form of alternating-current potentiometer, particularly adapted to telephonic-frequency measurements, and which gives its readings in two rectangular components of the voltage measured.

Brief History.—The name "Electric Potentiometer" was suggested in 1873, by Latimer Clark, for the instrument which he described, as serving to measure continuous-current potential differences, in a paper read in London, January 22, 1873, before the "Society of Telegraph Engineers," the forerunner of "The Institution of Electrical Engineers." This instrument has remained almost unchanged to the present time, and is one of the most valuable measuring instruments which electrical engineering possesses.

An early form of *a-c.* potentiometer was described by Franke in 1891. It employed a small *a-c.* generator with two armature windings mechanically adjustable with respect to a common rotating field; so that both the relative magnitudes and the relative

* Communicated by Dr. Kennelly.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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phase of the two induced *emfs.* at one and the same frequency, could be determined.[1]

An improved *a-c.* potentiometer was described by Dr. C. V. Drysdale[2] in 1909. This instrument has come into fairly extensive use. It measures an *a-c.* potential difference in polar coördinates, over the complex plane; *i.e.,* in size and in slope or phase, with respect to a certain phase standard. Its readings are therefore presented in the general form $E \angle \beta°$, such as $1.500 \angle 125.3°$ volts. Its range, without any auxiliary multiplier, is from 0 to 1.8 volts in size, and 0 to 360° in slope. The range in frequency which it claims is from 25 to 1000 ∞. The Drysdale *a-c.* potentiometer has filled a great need for a laboratory instrument capable of measuring planevector[3] voltages. For many such purposes its use is invaluable. When, however, the source of testing current is an oscillator, and not an alternator, there is a difficulty in using this instrument, because the excitation of the necessary phase-shifting transformer requires more than 60 watts. When an oscillator is used as the source of alternating currents, it is necessary to reduce the power absorbed in the measuring instruments to the lowest available limits. The use of oscillators for such purposes is steadily increasing. It then becomes imperative to adopt such a form of *a-c.* potentiometer as will avoid the use of an electromagnetic phase-shifting device.

Prof. A. Larsen described in 1910,[4] a form of two-dimensional potentiometer, the connections of which appear in Fig. 1. It consists of a non-inductive resistance *AB*, in series with the primary winding of an induction coil *BC*, an adjustable portion of the

[1] "Die elektrichen Vorgänge in den Fernsprechleitungen und-Apparaten," by Ad. Franke, Berlin, 1891. Thesis towards the Doctorate at Berlin University.

[2] "The Use of the Potentiometer on Alternating-Current Circuits." *Phil. Mag.,* Vol. 17, p. 402, Mar., 1909; also *Proc. Phys. Soc.,* London, Vol. 21, p. 561, 1909; also *The Electrician,* Vol. 63, p. 8, April 16, 1909; and Vol. 71, pp. 687–690, Aug. 1, 1913.

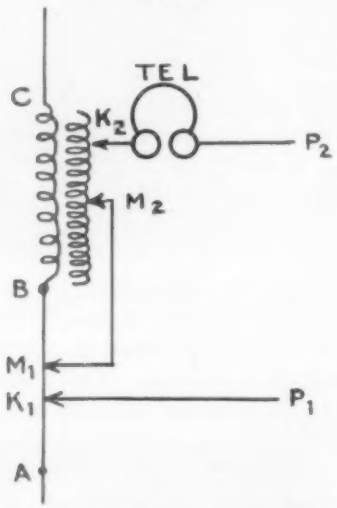
[3] "A planevector" may be defined as a geometrically directed complex quantity in a plane of reference, and subject to the laws of complex arithmetic, as distinguished from a "vector" which is subject to the laws of vector arithmetic and is not necessarily confined to a plane. In this paper, the term "vector" is used as an abbreviation for "planevector."

[4] A. Larsen: "Der Komplexe Kompensator, ein Apparat zur Messung von Wechselströmen durch Kompensation." *Elek. Zeitschrift,* 13th Oct., 1910, Vol. 31, pp. 1039–1041; also *The Electrical World,* Vol. 56, Nov. 3, 1910, pp. 1085–1088.

secondary winding being connected in series with an adjustable portion of the resistance AB, so that the vector sum of the resistance drop in AB between M_1 and K_1, and the mutual reactance drop between M_2 and K_2, shall be equal to the planevector *p.d.* to be measured, between leads P_1P_2, as determined by silence in the telephone.

The construction of a resistance-mutual-inductance potentiometer, on the Larsen principle, was taken up in 1916, in the electrical-engineering research laboratories of the Massachusetts Institute of Technology, by Mr. Alfred E. Hanson, in his thesis

FIG. 1.



Connections of Larsen potentiometer.

work towards a master's degree. In connection with this thesis,[5] the new type of potentiometer here described was designed.

New Instrument.—The electrical connections of the new instrument are indicated in Fig. 2, and are in all essentials the same as in Fig. 1. The resistance OA contains 50 ohms, in short coils, of *Ia-Ia* wire, wound both anti-inductively and anti-condensively, and also a short length of slide wire of 0.5 ohm. The mutual inductance coil has two equal copper windings, each having 8.8 ohms resistance at 20° C., and 3.9 millihenrys self-inductance.

[5] "The Design and Construction of an Alternating-Current Potentiometer," by Alfred E. Hanson, September, 1916; a Thesis towards the degree of M.S. in Electrical Engineering at the Mass. Inst. of Technology.

The mutual inductance between the two windings is approximately 3.85 millihenrys. The *p.d.* to be measured is connected to the terminals *pp'*. A vibration galvanometer *V.G.* serves as the balance indicator.

FIG. 2.

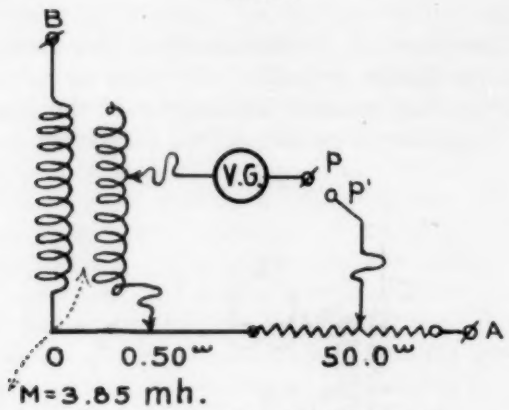


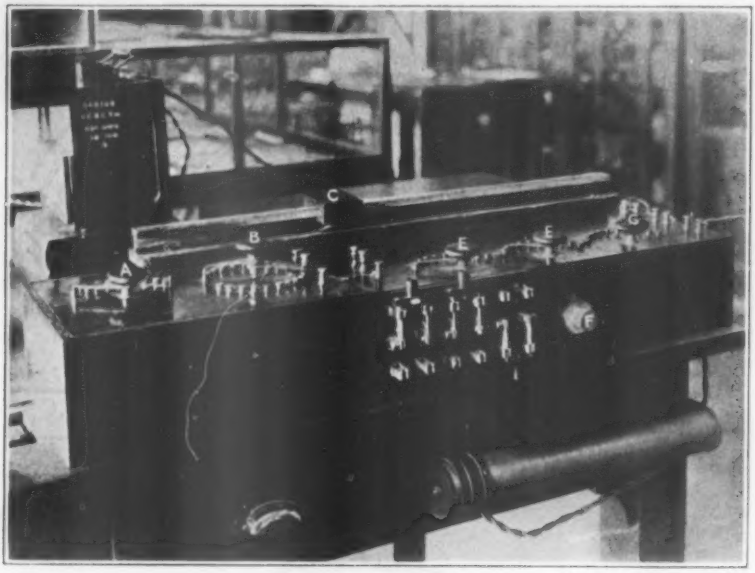
Diagram of connections in new potentiometer.

Fig. 3 shows the general appearance of the Hanson form of potentiometer. The dial switches *A* and *B* control the resistance taps; while the slider *C*, moving over the resistance wire, serves for a fine adjustment of resistance. The dial switches *E*, *F*, and *G*, control secondary taps in the mutual inductor, *E* being for 200 turns per step, *F* 20 turns per step, and *G* 2 turns per step. A fraction of one turn may be added, by turning the handle *f*, as will be described later.

The interior of the mutual inductance box is shown in Fig. 4. The winding is toroidal in form, comprising 41 wooden sectors of suitable taper, as shown in Fig. 5b. The dimensions of one sector appear in Fig. 5a.

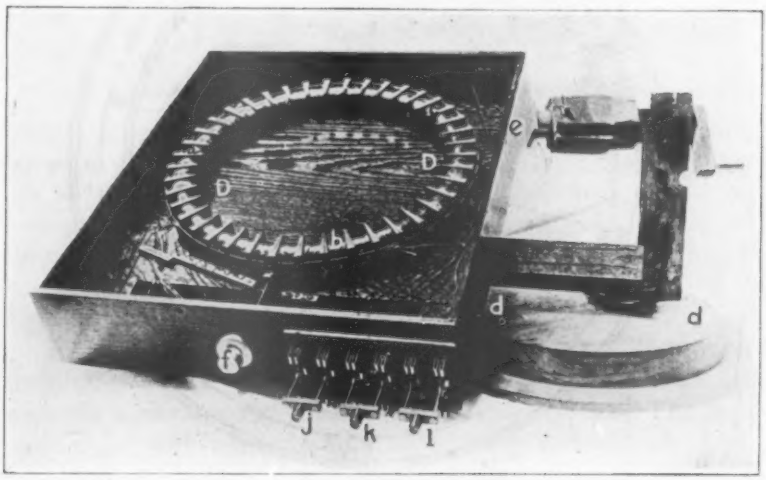
Each sector is first wound with a primary winding of 50 turns of No. 21 B. and S. gage double silk-covered copper wire (bare diam. 0.72 mm.) in 2 layers of 25 turns each. Over this primary winding is laid one layer of varnished cambric insulation. Over this insulation is a secondary winding, also 50 turns of the same size wire, in 2 layers of 25 turns each. In some of the bobbins, taps have to be brought out from the secondary winding. The mean diameter of the toroid is 36.8 cm. When all the sectors are assembled, and connected in series, the winding forms a

FIG. 3.



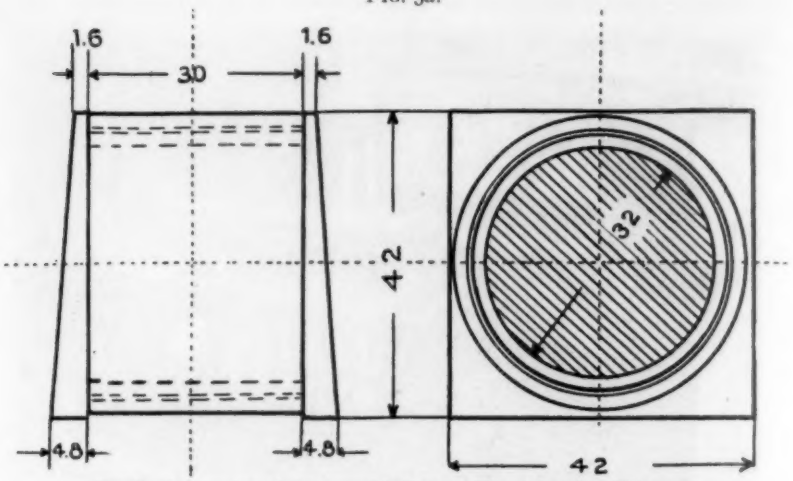
General view of potentiometer.

FIG. 4



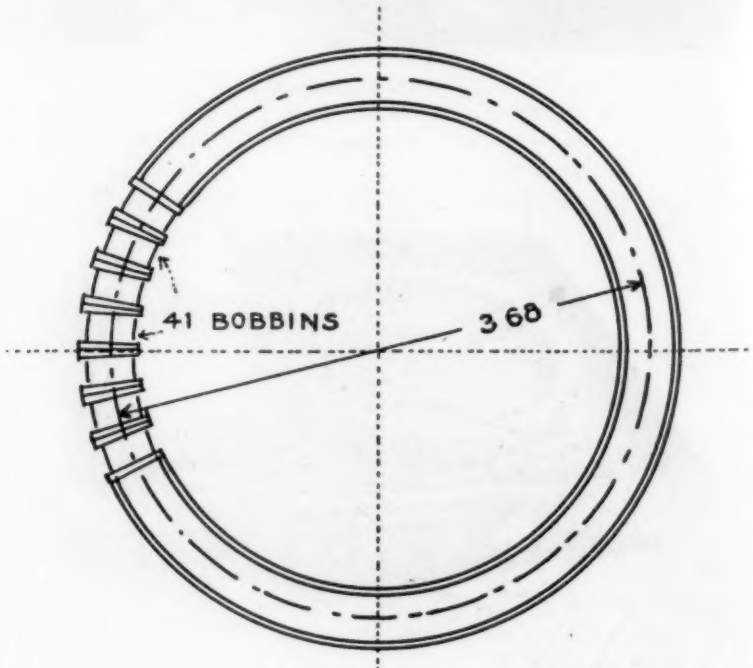
Interior of mutual inductor.

FIG. 5a.



Details of one sector of the mutual inductor. Dimensions in millimeters.

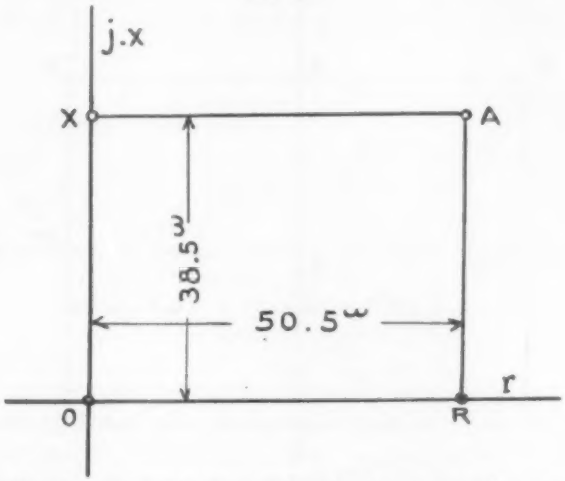
FIG. 5b.



Plan diagram of toroidal mutual inductor. Dimensions in millimeters..

closed circular solenoid with wooden core, devoid of screws or other metallic attachments. A wooden disk *dd*, Fig. 4, serves to support all the individual sectors in their proper places, when glued in position at *DD*. The advantages of the toroidal form of winding are, first, that the external magnetic field is then negligibly small, so that the primary current produces no appreciable stray field in the neighborhood of the apparatus; and second, that with accurate mechanical construction, the mutual inductance between the primary winding and the secondary coils should be proportional to their number of turns. One of the individual wooden

FIG. 6.



Range of impedance covered by the potentiometer, at ω 10,000 radians per second.

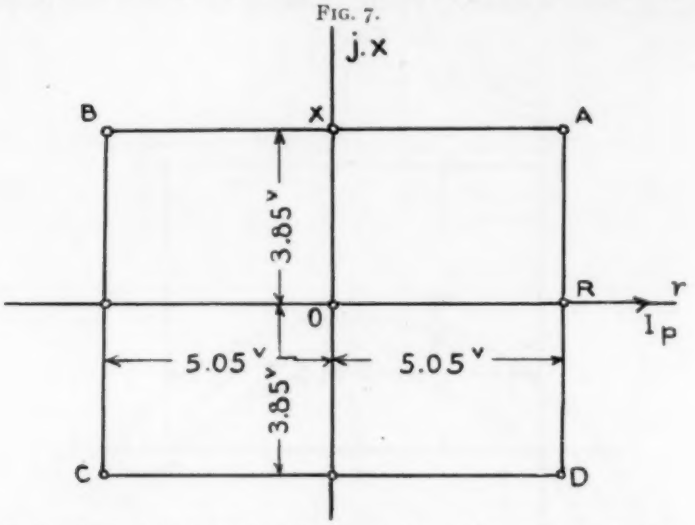
sectors is shown at *e*, held in a winding clamp. The handle *f* connects mechanically, by a spindle, with a single turn of secondary winding, situated in a hollow space at the centre of the core, between two adjacent coil sectors. The range of rotation of *f*, between the limits of $-90°$ and $+90°$, or half a turn, provides the same total change of mutual inductance as one step in the lowest dial.

Rectangular Range of Instrument.—Fig. 6 is a rectangular-coördinate diagram, indicating the range in impedance available with the apparatus for potentiometer measurement. The resistance $OR = 50.5$ ohms, and at $\omega = 10{,}000$ radians per second ($f = 1591$ ∽), $jM\omega = j\,38.5$ ohms. At any other frequency, the value of the mutual reactance will be varied proportionately.

Any impedance at $\omega = 10{,}000$, within the area *ORAX* on the diagram, can be covered by the simple series connection of resistance and secondary winding shown in Fig. 2.

Fig. 7 is a similar rectangular coördinate diagram, indicating the range in planevector voltage available with the apparatus for potentiometer measurement. If the *r.m.s.* current I_P supplied to the instrument, is 0.1 ampère, or 100 milliampères, taken at standard phase, and also at the frequency of reference ($\omega = 10{,}000$), the voltage that can be covered in the first quadrant is

FIG. 7.



Rectangular range of planevector voltage covered at $\omega = 10{,}000$ and $I_P = 0.1$ ampère.

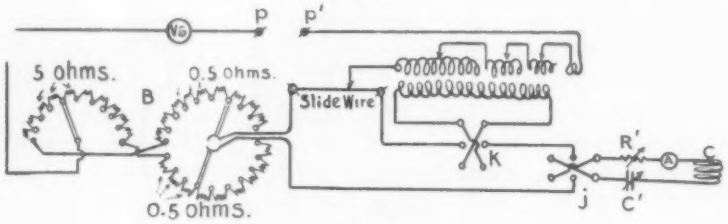
comprised within the rectangle *ORAX*, and so the maximum *p.d.* within reach of the potentiometer is $5.05 + j\ 3.85$ volts. At any other current strength, the voltage developed in the apparatus will be varied proportionately. Any voltage within the field *ABCD*, Fig. 7, can similarly be covered at $\omega = 10{,}000$, and $I_P = 0.1$ ampère, by suitably reversing either the R or jX components, or both. These reversals are easily made, by means of switches j and k, Fig. 4.

Electrical Connections.—The full connections of the instrument are indicated in Fig. 8. The coil C is the secondary winding of an oscillator of adjustable frequency, which supplies testing current to the apparatus. The resistance R' and the condenser C' are used to adjust the potentiometer current in size and in slope.

The switch j serves to reverse both R and jX. The switch k reverses jX separately. B is a compensating rheostat, so arranged as to keep the total resistance in the circuit constant, while changing the resistance between the tapping points. The unknown *p.d.* is connected to the terminals pp'. The vibration galvanometer, by means of which a balance is secured between the adjusted and unknown vector *p.d.s*, is indicated at *V.G.*

Method of Measurement.—The vibration galvanometer is at first heavily shunted, and is tuned to maximum response for the impressed frequency. The correct quadrant to employ is first found by using switches j and k. Successive adjustments are then made in R and jX, until the vibration galvanometer deflection is a

FIG. 8.



Detailed connections of the potentiometer.

minimum. The galvanometer shunt is now reduced, and the adjustments of R and jX repeated, until a sufficiently satisfactory zero balance has been obtained on the galvanometer.

Absolute and Relative Measurements of P.D.—Two general methods are available for use with potentiometers such as the one here described; namely,

(1) The method of absolute potential differences, secured by passing a measured constant current through the potentiometer, which current is taken as of standard phase.

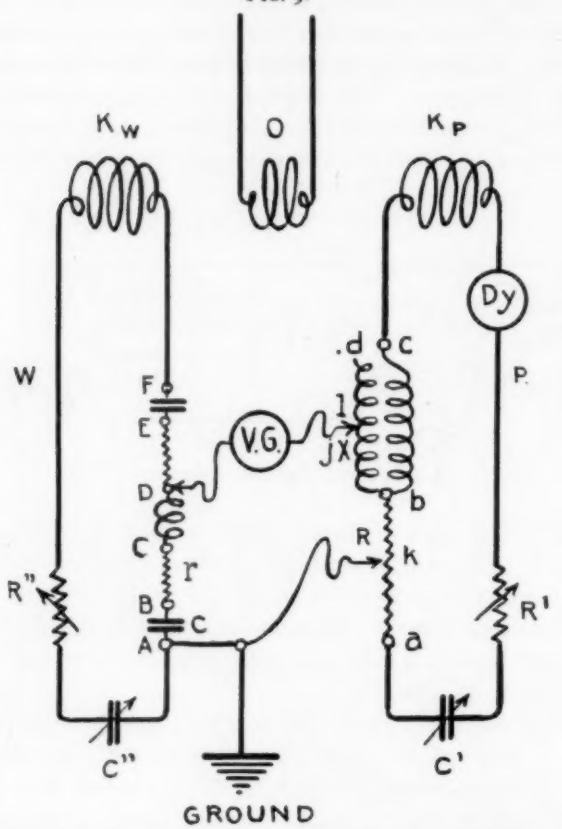
(2) The method of relative potential differences, secured by passing a constant, but unmeasured current, through the potentiometer, whose readings are then uncalibrated, but which become capable of calibration, by being compared with the reading across a certain impedance which is maintained as a standard of reference.

The first method has the advantage that it enables the potenti-

ometer readings to be stated directly in rectangular-coördinate volts. It has, however, the disadvantage of requiring the measurement of the potentiometer current to an even greater degree of precision than that aimed at in the potentiometer work.

In most laboratory measurements of alternating *p.d.*, relative

FIG. 9.



Simplified diagram of connections, showing the rectangular potentiometer *P* arranged for exploration of the potential distribution over the working circuit *W*.

values only are required, and thus it is the ratio of two measured voltages which is of immediate importance. Such ratios can be determined by the relative method, without the necessity of measuring the potentiometer current. The absolute method has, however, to be resorted to, when, as in iron-cored instruments carrying alternating currents, the impedance is a function of the

current strength, and therefore departs from Ohm's law. In all measurements of *p.d.* in circuits which obey Ohm's law, the second or relative method is to be preferred. Both methods of using the new instrument have been tried.[6] In the absolute method, the potentiometer current was measured by a differential dynamometer.[7] This plan was found to work well, although a considerable amount of care was required for the measurement of the potentiometer current. In the progress of the experimental work, however, the relative method was found to be increasingly advantageous.

The essential connections of the second or relative method are presented in Fig. 9. The oscillator coil or source of alternating *emf.* is marked *O*. This coil is inductively connected with each of two circuits; namely (1) the potentiometer circuit *P*, and (2) the tested or working circuit *W*. The *P* circuit contains the tuning condenser *C'*, and the adjustable resistor *R'*, as well as the potentiometer *abc*. The *W* circuit may contain any set of apparatus in which potential differences are to be measured. As shown in the figure, the *p.d.* at the terminals *AD* is being led to the potentiometer through the tuned vibration galvanometer *VG*. In the second or relative method of testing, the drop of potential between terminals *B* and *C* on resistance *r* may be used as the standard *p.d.* Then if the device to be tested in the working circuit is the condenser *c*, the terminals *AB* can be connected immediately afterwards to the potentiometer. As will be shown later, it is important to maintain a ground connection at the point *A*. Consequently, the drop across any single element, such as *BC*, is obtainable as a vector difference between that across *AC* and that across *AB*.

Let r be the standard impedance of known slope (which in the case of a strictly non-inductive resistance would be zero) (ohms $\angle$)

Z be the unknown impedance of the condenser c to be measured (ohms $\angle$)

I_P be the *r.m.s.* current in the potentiometer circuit (ampères $\angle$)

I_W be the *r.m.s.* current in the working circuit (ampères $\angle$)

$R_1 + jX_1$ the reading of the potentiometer across terminals *AC*.

$R_2 + jX_2$ the reading of the potentiometer across terminals *AB*.

[6] "Alternating-Current Potentiometry at Telephonic Frequencies," by Edy Velander; a thesis towards the A.M. degree at Harvard University, June, 1918.

[7] "Precise Measurements of Alternating Currents," by C. O. Gibbon, *Electrical World*, May 11, 1918, pp. 979–981.

Then the drop across the standard resistance r will be

$$I_P(R_1 + jX_1) - I_P(R_2 + jX_2) = I_P(R_0 + jX_0) = I_W r \text{ ..volts} \angle \quad (1)$$

In the AB connection, we have

$$I_P(R_3 + jX_3) = I_W Z \text{ .....volts} \angle \quad (2)$$

Dividing (2) by (1)

$$\frac{Z}{r} = \frac{R_3 + jX_3}{R_0 + jX_0} \text{ .....numeric} \angle \quad (3)$$

This procedure assumes that I_P remains the same in both tests, and also I_W. When, however, a high degree of accuracy is required. this assumption cannot be made. Suppose that in the first test I'_P is the vector potentiometer current, and I'_W the vector working current. Next suppose that when the second measurement is made, both the sizes and the slopes of these currents may have slightly changed, so that I''_P is the new potentiometer current, and I''_W the new working current. Then rewriting (1) and (2) accordingly, we have

$$\frac{Z+r}{r} \cdot \frac{I'_W}{I''_W} = \frac{R_1 + jX_1}{R_2 + jX_2} \cdot \frac{I'_P}{I''_P} \text{ .....numeric} \angle \quad (4)$$

If, however, the potentiometer current and the working current vary together, so that the vector ratios remain equal:

$$\frac{I'_W}{I''_W} = \frac{I'_P}{I''_P} \text{ .....numeric} \angle \quad (5)$$

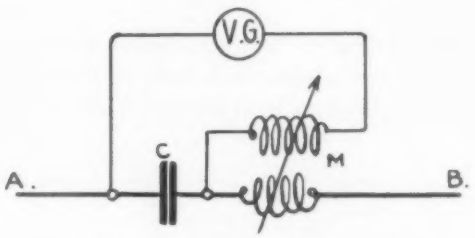
Then equation (3) will still hold. If, then, the mutual inductances between the primary coil, and each of the two secondary coils K_P and K_W remain constant, also the mutual inductance between K_P and K_W; likewise the impedance in each of these circuits; then any variation of current in the primary coil, due to unsteadiness in the oscillator, will not affect the vector ratios of equation (5), and will therefore not affect formula (3). If, however, the frequency impressed by the oscillator varies, then the above reasoning will not hold, and the method will be vitiated. It is therefore necessary that the frequency should be maintained constant within satisfactorily close limits. It should be noted that during *a-c* potentiometer tests, no appreciable change should

be made in the load upon the oscillator; because any change in this load produces some corresponding change in the oscillator frequency.

Frequency Measurements.—It will be evident from the foregoing, that careful measurements of the impressed frequency are necessary in the use of the *a-c* potentiometer.

Probably the simplest device for the measurement of the impressed frequency is the Campbell condenser and mutual inductance branch circuit[8] of Fig. 10. Here a condenser of C farads is shunted by the secondary coil of a mutual inductance of M henrys and a vibration galvanometer VG. One or both of these

FIG. 10.



Campbell frequency-measuring arrangement.

elements is varied, until the galvanometer shows no current. We then have, if I is the vector current in the circuit (ampères $\angle$)

$$jM\omega I + I\frac{1}{j\omega C} = 0 \quad \text{volts}\angle \quad (6)$$

whence

$$\omega = \frac{1}{\sqrt{MC}} \quad \text{radians / sec.} \quad (7)$$

Strictly speaking, this zero current in the vibration galvanometer can only be secured if (1) there is no effective resistance in the condenser, and (2) no effective capacitance in the secondary coil. Owing to the great difficulty of securing these conditions, to the necessary degree of precision, a sharp zero balance is hard to obtain. The modification of connections shown in Fig. 11 enables this difficulty to be overcome. A large resistance R, of say 2000 ohms, is connected through an adjustable small inductance l, as a shunt to both the condenser and mutual-inductance primary. The secondary is led through the vibration

[8] A. Campbell. *Phil. Mag.*, May, 1908, Vol. 15, p. 166.

galvanometer to an adjustable tap on the resistance. If the condenser current is represented by I_c *r.m.s.* ampères $\angle$, and the current in the resistance by I_R *r.m.s.* ampères $\angle$, then with V_{AB} *r.m.s.* volts $\angle$ as the *p.d.* between A and B, at balance,

$$I_c = \frac{V_{AB}}{r+j\left(L\omega - \frac{1}{C\omega}\right)} \quad \text{ampères } \angle \quad (8)$$

and

$$I_R = \frac{V_{AB}}{R+jl\omega} \quad \text{ampères } \angle \quad (9)$$

r being the effective resistance of the secondary winding in ohms. The *p.d.* in the galvanometer circuit will be

$$jM\omega I_c + kRI_R = 0 \quad \text{volts } \angle \quad (10)$$

where kR is the resistance included between B and the tapping point. After this zero balance has been obtained, first by assigning k and C, with a final adjustment in M and l, we have

$$\omega = \frac{1}{\sqrt{C\left(L+\frac{M}{k}\right)}} \quad \text{radians / sec.} \quad (11)$$

with the further condition that l has had to be adjusted to

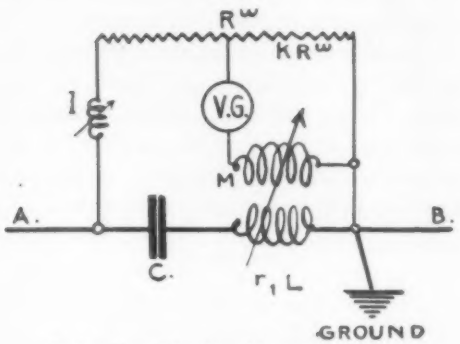
$$l = CRr\left(1+\frac{kL}{M}\right) \quad \text{henrys} \quad (12)$$

This method enables a sharp balance to be obtained at the expense of the additional adjustments. Moreover, since $1/k$ may conveniently be made a large number, C and M can both be kept reasonably small, even at low frequencies.

The same connections are presented in Fig. 12, under the form of a generalized Heaviside bridge. Formulas (8) to (12) apply equally well to this case.

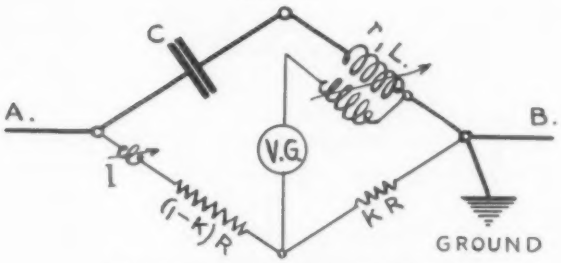
In both Figs. 11 and 12, a ground connection is indicated in the frequency measuring set, at the point B. As will be mentioned in connection with sources of error in the use of the potentiometer, the selection of a proper ground point is vital to the accuracy of the measurements. At frequencies higher than, say, 100 cycles per second, parasitic alternating currents, due to distributed capacitance in the apparatus, play an increasingly prominent part. At very high frequencies, such parasitic currents may even swamp the working current. Either the point A, or the point B may be grounded in Figs. 11 and 12; but prefer-

FIG. 11.



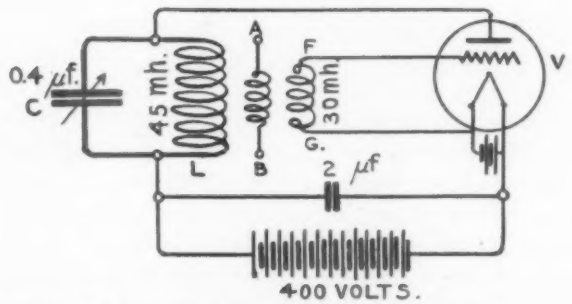
Preferred modification of frequency measurer.

FIG. 12.



Bridge arrangement of connections in Fig. 11.

FIG. 13.

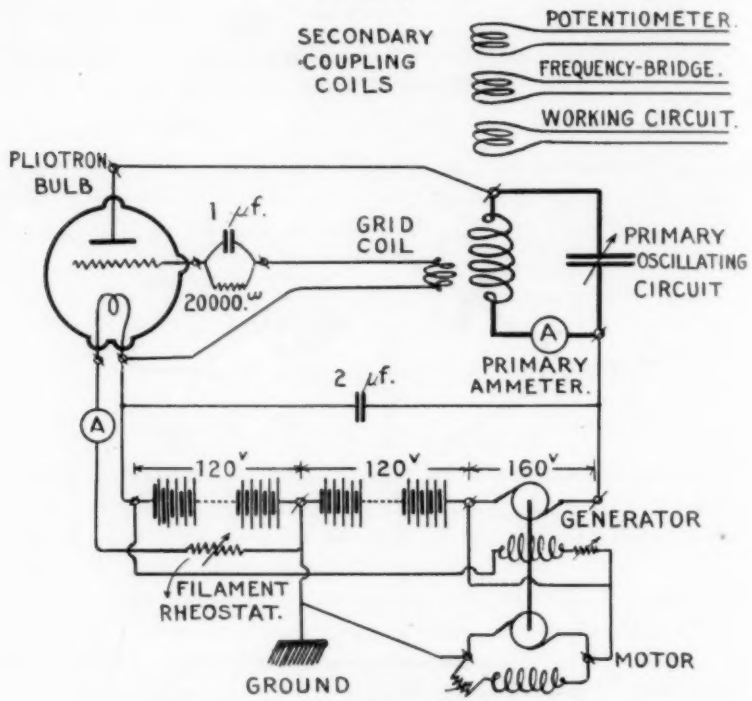


Pliotron connections; skeleton plan of connections.

ably *B*, owing to the preponderating distributed capacitance of the mutual inductor.

Oscillator.—A convenient set of vacuum-tube generator connections appears in Fig. 13. *V* is a 3-electrode vacuum-tube of a pliotron oscillator or similar type, with its plate, grid and filament. The main oscillation circuit consists of the adjustable condenser *C* and inductance *L*. The grid-coil secondary winding *FG* supplies the oscillating excitation to the grid. The secondary

FIG. 14.



Arrangement of the pliotron as a generator.

winding *AB* may be connected to the potentiometer circuit. Several such secondary coils may be used. The continuous *emf.* may be supplied by a small dynamo generator. If possible, this generator should be driven by a motor actuated by storage battery for steadiness of action. An auxiliary condenser of $2\mu f$ serves as a high-frequency bridge across the inductance of the generator.

A more detailed set of connections, showing an actual arrange-

ment employed, appears in Fig. 14. In this case, 240 volts of continuous plate *emf.* was derived from a storage battery, and 160 volts from a generator which was storage-battery-motor driven.

A Vreeland oscillator was also used in the earlier measurements. This apparatus is too well known to need special description. With the Vreeland oscillator employed, the available range of frequency, without external auxiliary apparatus, was from 400∽ to 2500∽. With the pliotron oscillator, the available range of frequency was limited only by the capacitances and inductances employed in the oscillation circuit.

Vibration Galvanometer.—In nearly all of the measurements made with the apparatus, a Duddell bifilar vibration galvanometer, adapted for use up to a frequency of 2000∽, was employed as the balance detector. This served the purpose satisfactorily when properly tuned to the impressed frequency. When *p.d.* measurements are made upon apparatus of high internal impedance, a detector of greater sensitivity and corresponding impedance would be preferable. A pair of head telephones of suitable impedance were found to work well in such cases. A crystal detector with *d-c.* galvanometer was also used successfully.

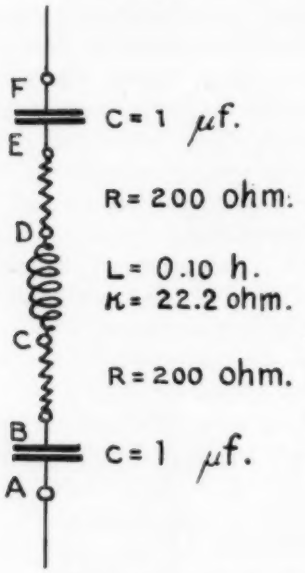
Example of the Use of the Instrument in a Simple A-C. Circuit.—As an example of the measurements that may be made with the instrument, we may consider the simple series circuit *ABCDEF* in Fig. 15, consisting of a fixed mica condenser *AB* of 1.0 microfarad, in series with an anti-inductive metallic resistance *BC* of 200 ohms, followed by a non-ferric inductance *CD* of 100 millihenrys and 22.2 ohms, followed again by an anti-inductive resistance *DE* of 200 ohms similar to *BC*, and finally by a second mica condenser *EF* of 1.0 microfarad.

The electrical connections for exploring the potentials along the work series *AF*, Fig. 15, are indicated in Fig. 9. When using the absolute method, the differential dynamometer, *Dy*, measures the *r.m.s.* alternating current strength supplied in the potentiometer circuit, and thus furnishes the voltage scale $E = IR + jIX$, obtained for any reading of R and jX. Fig. 16 shows the results actually obtained in this way, at an impressed frequency of 500∽, with a current of 0.020 ampère in the potentiometer circuit. The grounded point *A* was kept fixed, and measurements were made by shifting the lead of the tuned vibration galvanometer along the points *B*, *C*, *D*, *E* and *F* in succession. These vector *p.d.s* are indicated in Fig. 16 by the vectors *AB*, *AC* . . .

AF, respectively. The straight lines connecting the adjoining pairs of points *BC*, *CD*, *DE* and *EF* on the diagram, then become the inferred vector potential drops in the successive elements of the circuit, all presented to the particular phase of the potentiometer current as standard.

It will be observed that the lines *BC* and *DE* are parallel. The direction of these lines shows the phase of the current in the working circuit, assuming that the anti-inductive resistances *BC* and *DE* may be regarded as pure resistances, at the test frequency

FIG. 15



Simple series circuit explored.

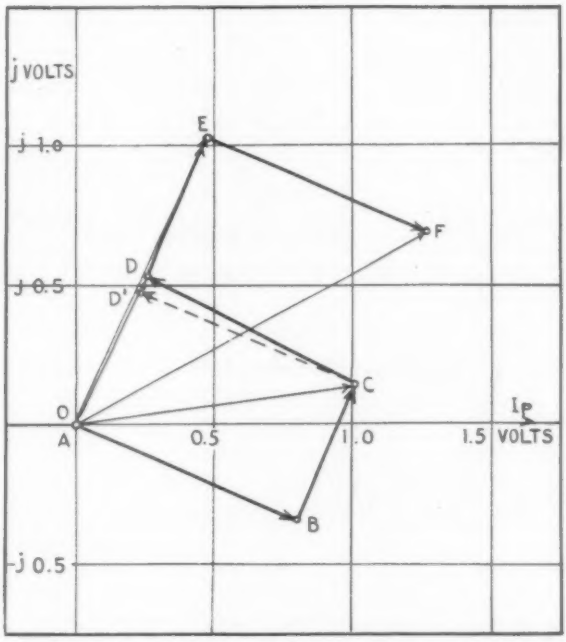
of 500 ∽. The lines *AB* and *EF* on the diagram are also parallel to each other, and are perpendicular to the lines *BC* and *DE*. This shows that the voltages at the terminals of the condensers lag substantially 90° behind the current in the working circuit, according to the regular theory. The line *CD* is the drop in the inductance coil, and may be analyzed into two mutually perpendicular components; namely, *D'D* in phase with the current, due to the presence of resistance, and *CD'* in leading quadrature with the current, due to the inductive reactance of the coil.

If we replot the diagram to working-current standard phase,

as in Fig. 17, we rectify the diagram by a virtual rotation of approximately 65° in the clockwise direction. The various voltage drops are then read off, to rectangular coördinates, in the customary manner.

The diagram of Fig. 17 gives a correct presentation of the voltage drops in each or any series combination of the elements in the working circuit, provided that the potentiometer current I_P has been measured. In order to evaluate the impedance of the

FIG. 16.

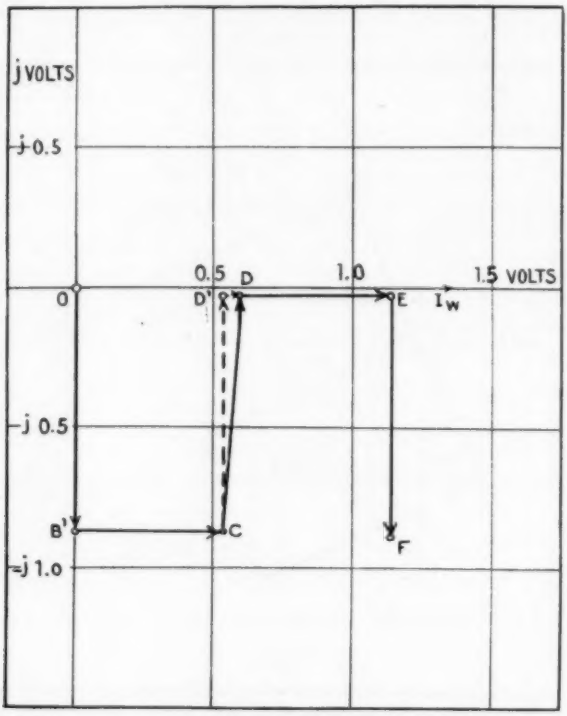


Distribution of planevector voltage along series AF, Fig. 15, at 500 ∽, to potentiometer current standard phase.

corresponding elements, it becomes also necessary to know either the magnitude of I_W, the working current; or, the vector impedance of one of the elements. Thus, if the resistance BC is a standard resistance of 200 ohms, the scale of the entire diagram can be interpreted in ohms. It should be observed that the measurement of I_P, the potentiometer current, with R and jX, is insufficient to determine the impedances of the elements in the working circuit, and that while it would be possible to measure both I_W and I_P, this double operation becomes burdensome and

unnecessary, so that the use of the instrument naturally leads to the relative method of measurement, in which no current strength has to be determined, but a standard impedance—preferably a standard pure resistance—is included in the working circuit. Measured potential drops on unknown impedances are then referred to the measured drop on this standard, as a working unit.

FIG. 17.



Distribution of planevector voltage in Fig. 16, referred to working current standard phase.

Sources of Error and Their Elimination.—It is impossible to work for any length of time with any *a-c.* potentiometer at a telephonic frequency, without encountering discrepancies in the measurements, which are attributable to the well-known disturbance from parasitic currents in the distributed capacitance of the tested apparatus. The first step in the elimination of these superposed parasitic currents is to ground a suitable point in the working circuit, so as to bring that point to zero potential, and prevent the distributed capacitance in the immediate neigh-

borhood of that point from producing a parasitic condenser current. In general, the ground should be established at one end of the range of the elements in the working circuit to be measured. As an example, Fig. 9 shows a ground established at the point A.

Suppose that the ground is established at the junction B of two impedances AB and BC to be compared, such as Z_1 and Z_2 in Fig. 18, and that I_W is the working current in the absence of distributed capacitance, and therefore equal in the two impe-

FIG. 18.

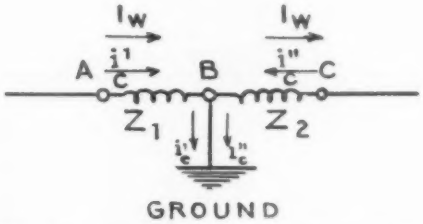


Diagram illustrating the effect of improper grounding.

dances. The current i'_c in Z_1 represents a small parasitic current of a certain magnitude and phase escaping to ground at B, while the current i''_c in Z_2 is a similar small parasitic current which, in general, will have a different magnitude and phase, also escaping to ground at B. The resultant working currents in the two impedances will then be the vector sums $(I_W + i'_c)$ and $(I_W - i''_c)$ ampères, respectively. The ratio of the potential drops in the two impedances will then be

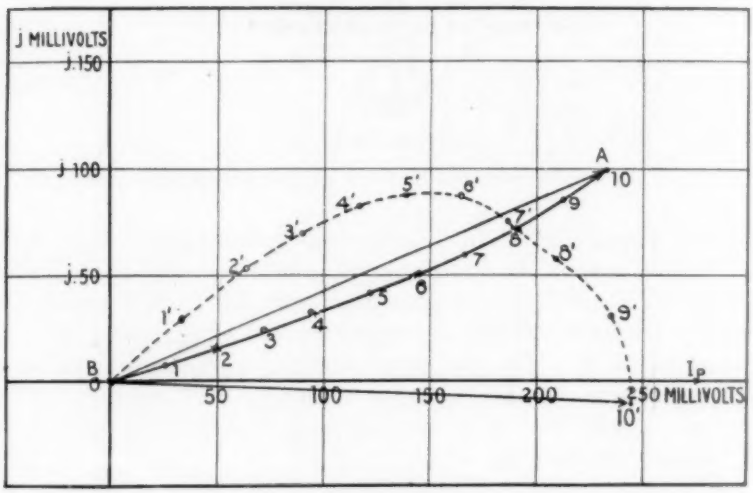
$$\frac{(I_W + i'_c)Z_1}{(I_W - i''_c)Z_2}$$

which, in general, will differ from the required ratio, $\frac{Z_1}{Z_2}$ by an unknown amount.

In cases where the quantity to be determined is a potential difference distribution, rather than an impedance comparison, the importance of a proper grounding point in the working circuit is equally great. It is evident that, as a general rule, during a set of *p.d.* measurements on the same working circuit, the grounded point should not be shifted. This is for the reason that when the ground connection is shifted, the potential of all points along the circuit with respect to the ground is varied, thereby changing the entire distribution of parasitic currents.

An experimental example of the effect of shifting the ground connection in a working circuit appears in Fig. 19. Here a standard resistance box of 100,000 ohms, in 10 series coils of 10,000 ohms each, was inserted in the working circuit, as shown in Figs. 20a and 20b. In Fig. 20b, the vibration galvanometer connection to the potentiometer is carried permanently to the end *B* of the resistance box. Since it is manifestly inadmissible to establish a ground connection on this lead, as it would bring parasitic current directly through the galvanometer, the ground has to be established at *t*, the travelling lead to the potentiometer.

FIG. 19.



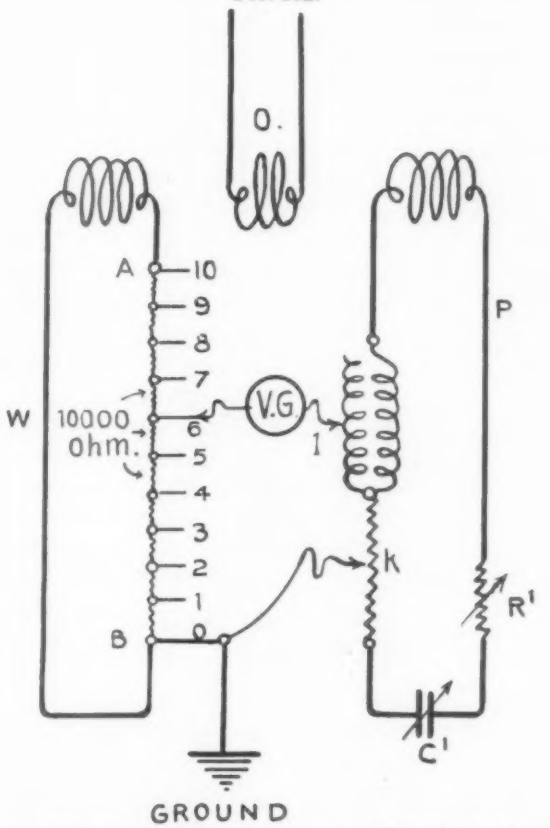
Distribution of planevector voltage along 100,000-ohm resistance box. Small circles indicate observed values, crosses indicate computed values, assuming that each section of the box subtends a hyperbolic angle of 0.08 ∠45° hyp. radian.

This involves, however, a change in the distribution of potential and capacitance current at each change in the position of *T*. The result is shown in the broken curve 1′, 2′, 3′ of Fig. 19. The curve of *p.d.* between *A* and *B*, Fig. 20, should evidently be a uniform straight line *O*10′ in Fig. 19. The presence of the changing parasitic current distribution appears to have been responsible for the erratic curve shown. Assuming that the *p.d.* across the entire resistance box is correctly represented by the vector *O*10′, Fig. 19, then all of the intermediate *p.d.s* should be

situated along this straight line; whereas the actually measured *p.d.s* from *O* to the successive points 1, 2, 3, etc., Fig. 20b, follow the bending line 1′, 2′, 3′ . . ., etc.

The connections were then changed to those of Fig. 20a, in which the ground connection is kept fixed at *B*, and the travelling

FIG. 20a.



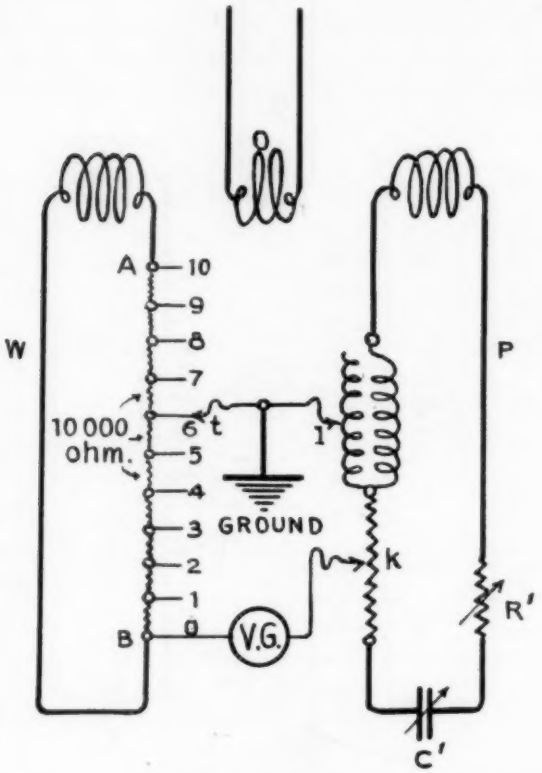
Exploration by means of the potentiometer *P*, of the voltage drop along a high-resistance box *A B*, of 100,000 ohms. Note correct position of ground-connection at *B*.

lead contains the vibration galvanometer. The corresponding vector curve of *p.ds* is shown at 1, 2, 3, 4, Fig. 19, and is a much closer approximation to a straight-line vector *OA*, representing the *p.d.* over the entire resistance. This curve resembles in form that presented by an artificial cable when an alternating *emf.*,

such as *OA* Fig. 19, is impressed on the sending end, while the distant end is grounded. The curve indicates that each section of the box subtends a small hyperbolic angle.

Applications of the New Form of A-C. Potentiometer.—A large field of experimental investigation in the laboratory lies

FIG. 20b.



Incorrect arrangement of ground-connection giving rise to the erroneous results 1', 2', 3' . . . . . in Fig. 19.

open to the *a-c.* rectangular potentiometer. The power it consumes is a fraction of 1 watt, while its range of voltage is extensive. It enables the vector *p.d.* on different parts of an alternating-current instrument, or on different sections of an alternating-current line, to be measured conveniently. The results are also of considerable educational value to the student. It is pro-

posed to communicate in another paper a number of the results obtained experimentally at various telephonic frequencies.[9]

It should be pointed out that the degree of precision obtainable with the instrument, although very satisfactory from an alternating-current standpoint, is not to be compared with that readily obtainable from the *d-c.* potentiometer. This relatively low precision is attributable to parasitic currents from distributed capacitance, and also to stray alternating magnetic fields. If these two sources of error could be eliminated, the precision of the instrument might be of the same order as that of the *d-c.* potentiometer.

Suggestions for Improvements in Construction.—A weak point in the design of the new instrument is the relatively high internal capacitance between the primary and secondary windings of the mutual inductor, which, at high frequencies, tends to produce impurity in the vector mutual reactance jX. This defect could be reduced by increasing the insulating spacing between the concentric primary and secondary windings on the toroid. At 2000~, the discrepancy due to this mutual capacitance appears by measurement, in this instrument, to be $(0.25 + j1.2)$ per cent. in voltage, but rapidly diminishes as the frequency is reduced. There is also a weak point in the toroidal form of mutual inductor, that although there is negligibly small stray alternating field produced in the apparatus by an exciting primary current, yet the secondary winding is not exempt from the influence of stray magnetic fields from external sources at testing frequency. Precautions should therefore be taken to remove the apparatus from the vicinity of alternating magnetic fields.

SUMMARY.

(1) The principle of the *a-c.* rectangular potentiometer here described is not new, but the form of the instrument appears to be new.

(2) By the use of this instrument, alternating *p.d.s* can be measured, to rectangular coördinates, up to at least 2000~, with only a small expenditure of power.

(3) The use of the instrument shows the marked influence of distributed capacitance in *a-c.* apparatus, and the importance of reducing this disturbing effect when measurements are made.

[9] *Proc. American Philosophical Society*, 1919.

(4) The importance of a proper ground connection in the working circuit is emphasized.

(5) The *a-c.* rectangular potentiometer escapes the necessity of measuring the strength of alternating current in either the potentiometer circuit, or the working circuit, provided that the relative method is used, and that the impressed frequency is maintained constant.

(6) Owing to the effects of distributed capacitance, the voltage distribution in a simple series resistance box, carrying alternating currents, fails to follow a vector straight-line law. The deviation tends to increase with the impressed frequency.

(7) The importance of reducing the mutual capacitance between the concentric primary and secondary windings of the toroidal induction coil, at high frequencies, is emphasized as the result of experimental tests.

Analysis of Statically Indeterminate Structures by the Slope Deflection Method. M. W. WILSON, F. E. RICHART and CAMILLO WEISS. (*Bulletin No. 108, Engineering Experiment Station, University of Illinois, 1919.*)—In recent years rectangular steel frames with riveted joints have been used, and many types of monolithic reinforced concrete frames have been developed. The use of statically indeterminate stresses cannot, accordingly, always be avoided. Structures are frequently made of an indeterminate type to secure economy of material. It is felt that analyses of statically indeterminate structures are desirable since such information will do much to inspire confidence in the reliability and in the economy of such structures.

An investigation of statically indeterminate structures has been conducted by the Engineering Experiment Station of the University of Illinois to obtain a convenient method of analyzing the moments, stresses and deflections for a number of typical structures. The analyses were based upon the assumptions that the connections are perfectly rigid, that the length of a member of a rectangular frame is not changed by axial stress and that the shearing deformation is zero. The method has been explained in sufficient detail to enable the designing engineer to use it in the solution of his problems. It is believed that the fundamental principles presented may be readily coördinated with the ordinary principles of mechanics so that the more complex and even the simpler problems may be studied from a new viewpoint.

THE PHENOMENA OF DRYING WOOD.*

An Analysis of the Internal Stresses Which Occur in Wood During the Progress of Drying from the Green Condition, with a Brief Discussion of the Physical Properties Which Affect These Stresses.

BY

HARRY D. TIEMANN, M.E., M.F.

Physicist and Dry Kiln Specialist, U. S. Forest Service.

INTRODUCTION.

But little knowledge exists, either among skilled artisans working with wood or among scientists, concerning the phenomena which take place accompanying the extraction of moisture from the green condition to the perfectly dry state. The U. S. Forest Service has devoted years of study to this subject and has derived many interesting facts and conclusions, although there is still much to be learned.

I will attempt to present here a complete summary of the main facts as far as known, together with a brief attempt to show the relationship of the stresses mathematically. Just how the water passes through the wood, from the centre to the surface, whether by capillary action, flow, or by repeated vaporization and condensation or a combination of these is still unknown, and I will not attempt at the present writing to burden the reader with a discussion of the theory concerning this process. Suffice it for the present to accept the fact that this action must take place in some manner in order that a solid block of wood dry. The physical factors influencing this transfusion of moisture, however, must needs be considered.

In order to get a clear conception of what takes place during this transfusion and evaporization of moisture, a knowledge of the wood substance itself and its relationship to moisture is absolutely essential. I must, therefore, prevail upon the patience of the reader by first setting forth as briefly as possible a description of this complex material with which we have to deal.

* Communicated by the Director of the Forest Products Laboratory, Madison, Wisconsin.

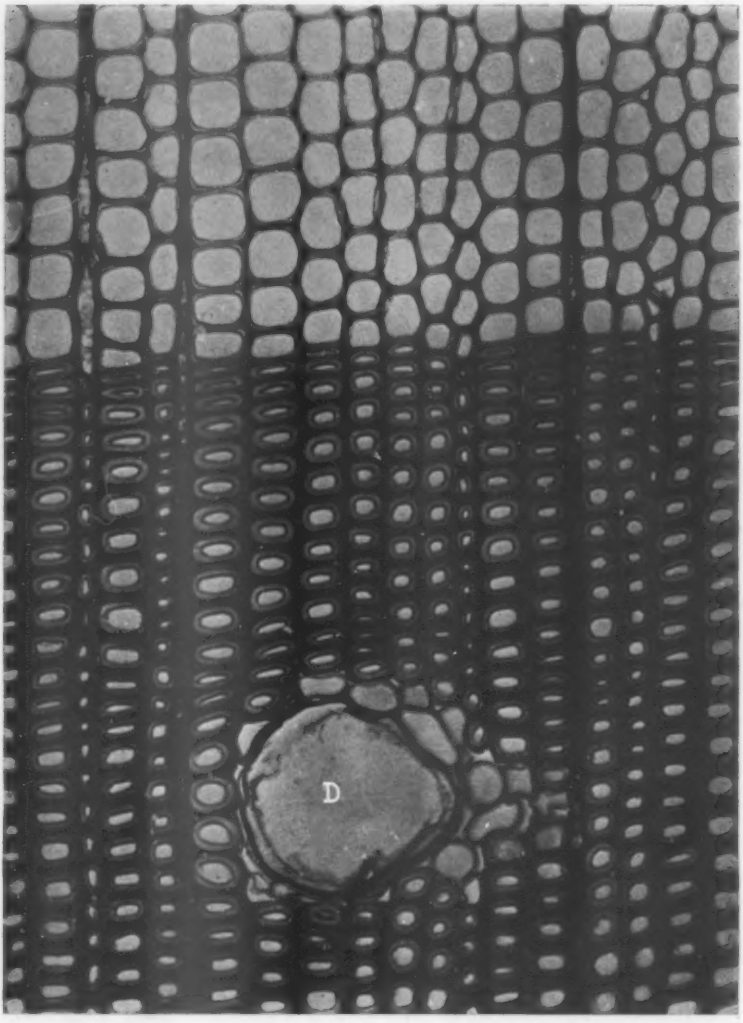
THE WOOD SUBSTANCE.

The substance of which wood is composed being organic is, therefore, very complex. It is half again as heavy as water, with a specific gravity of 1.56. It is thought to be built up of small particles closely laid together, the interstices being capable of filling up with moisture. The foundation part of this substance is known as cellulose. Cotton is almost pure cellulose, but in wood there is another material combined with the cellulose called lignin. This has never been isolated by itself, but is known only in combination with other substances. Just how it is combined with the cellulose is not well known. It adds to the strength of the cell walls and gives them a color. The elements of which cellulose is composed are combined in the same proportion as in starch, to which it is closely allied, although the molecule is differently arranged. Both are represented by the formula $(C_6H_{10}O_5)_n$, the hydrogen and oxygen being combined in the same proportion as in water. Sugars, gums, and resins are all closely related and it is probable that the living protoplasm is capable of transforming one into the other by the addition or subtraction of water from the molecule. This accounts for their common occurrence in living trees. For example, addition of hydrogen and oxygen in the proportion of water to the molecule of cellulose yields cane sugar, $2(C_6H_{10}O_5)+H_2O=C_{12}H_{22}O_{11}$. This conversion, however, does not take place in the simple manner indicated by the above equation, but the equation is given in order to show the relationship.

THE STRUCTURE OF WOOD.

Wood is made up of minute cells, arranged somewhat as the cells in a honeycomb except that the cells in wood are very much longer in proportion to their width than in a honeycomb and they are not as uniform. In the "softwoods" (gymnosperms) the vertical cells are fairly uniform in shape and size but in the hardwoods (angiosperms) they vary greatly, some being fifty times as wide as others, the wide ones being termed "vessels" and the narrow ones "wood fibres." Interspersed between these vertical cells and fibres and lying in a horizontal radial direction are the medullary rays, appearing as the "silver grain" on quarter-sawed oak. The medullary rays are composed of short, blunt, thin-walled cells, similar to pith tissue, and are shaped like two-edged swords set edgewise.

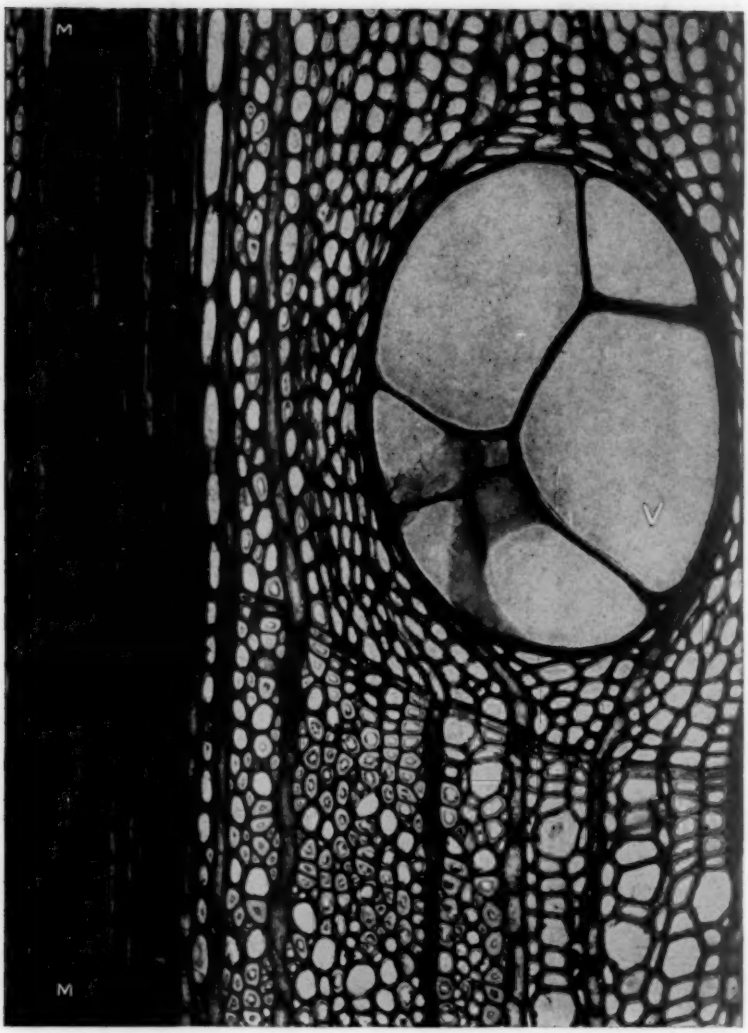
FIG. 1.



Microscopic section of a Gymnosperm ("Softwood"), a piece of shortleaf pine (*Pinus echinata*); at junction of two annual rings. The vertical lines are the medullary rays (radial). The centre of the tree is below. A resin duct D is visible in the "summerwood." Magnified 250 diameters.

Fig. 1 is a cross-section of a gymnosperm (*Pinus echinata*), and Fig. 2 of an angiosperm (*Quercus minor*), both magnified the same amount, 250 diameters.

FIG. 2.



Microscopic section of an Angiosperm ("Hardwood"), a piece of post oak (*Quercus minor*) at junction of the annual rings. An open vessel or "pore" V is shown in the springwood and a large medullary ray M (radial) on the left. The centre of the tree is below. Magnified 250 times.

THE FIBRE SATURATION POINT.

Water exists in green wood in two forms: As liquid water contained in the cavities of the cells or pores, and as "imbibed"

or hygroscopic water intimately absorbed in the substance of which the wood is composed. The removal of the free water from the holes or pores will evidently have no effect upon the physical properties or shrinkage of the wood,[1] but as soon as any of the "imbibed" moisture is removed from the cell walls shrinkage begins to take place and other changes occur. The strength also begins to increase at this time. The point where the cell walls, or wood substance, become saturated is called the "fibre saturation point," and is a very significant point in the drying of wood. In some cases the free water can be readily removed by heating above the boiling point, but in many cases this would injure the wood, and as a rule the water contained within the cells themselves can not be forced out in this manner, only that from the open vessels or pores (see Fig. 2) passing off in vapor. The chief difficulties, however, come in evaporating the free water where it has to be removed through its gradual transfusion through the cell walls instead of by boiling. The problem arises in the danger of drying the surface below its fibre saturation point while free water still remains in the interior. As soon as the imbibed moisture begins to be extracted from any portion shrinkage begins and stresses are set up in the wood which tend to cause checking. The fibre saturation point lies between moisture condition of 25 and 30 per cent. of the dry weight of the wood, depending on the species.[2] Certain species of eucalyptus, oak, and probably other woods, however, appear to be exceptional in this respect in that shrinkage begins to take place at a moisture condition of 80 to 90 per cent. of the dry

[1] An exception to this statement occurs in certain species, notably in western red cedar (*Thuja plicata*) and in redwood (*Sequoia sempervirens*), in which a collapse of the cell walls takes place in spots or bands during the evaporation of the free water. This collapse occurs only in excessively wet regions and when the wood is dried at too high a temperature. The explanation of this peculiar phenomenon appears to be that the cell walls, which are practically impervious to air while wet, but through which water may readily pass, become soft and plastic when heated. Under this condition those cells which are completely full of water to start with are subjected to an internal suction or tension produced by the depletion of the water in the cavity by its evaporation through the cell walls. The cells then collapse like rubber tubes, one layer after another.

[2] See Forest Service Circular 108—The Effect of Moisture on the Strength of Wood.

weight. It is possible that this apparent shrinkage may in reality be a form of collapse.

SHRINKAGE AND MOISTURE.

Wood in the living tree contains a great amount of moisture, varying from 30 per cent. in the heartwood of some conifers to over 200 per cent. of the dry weight in some of the hardwoods. This moisture must be removed before the wood is fit for use for most purposes.

Wood shrinks differently in different directions—as a rule it may be considered to shrink twice as much circumferentially as it does radially and about one-fiftieth as much longitudinally. Shrinkage continues until this substance is perfectly dry ("oven dry"), and the wood begins to swell again by absorption of moisture as soon as it is exposed to moist air. Alternate shrinking and swelling is inevitable with corresponding changes in the relative humidity of the surrounding air. This causes the so-called "working" of the wood. Different species vary greatly in this respect.

Now in the living tree the wood is always above its fibre saturation condition, so that dry wood may be looked upon as in a unique condition, in that it has never been dry since it was first formed.

DRYING.

The operation of removing the moisture from wood does not consist simply of evaporation. This, of course, would be merely a matter of supplying the necessary heat and removing the excess vapor. Wood is a complex substance and the removal of the moisture is accompanied by physical and chemical changes.

In order to pass out from the interior of a board or timber the water must ordinarily pass transversely from cell to cell and evaporate from the surface. It is true that it can travel lengthwise very much more rapidly, as is evidenced by the end checking of lumber, but end drying cannot be counted upon for removal of moisture from the centre of a long stick. This process of transfusion from cell to cell is very slow, so that it takes one-inch boards from six months to three years to thoroughly air dry, according to the species, the amount of water they contain when green, and the conditions of drying, such as method of piling, air conditions, etc. Even then, unless it is in an exceedingly dry

climate, the wood will rarely dry below 12 to 14 per cent. For thoroughly dry wood this must be supplemented by kiln drying.

Were it not for the unequal shrinkage and the slow rate of transfusion of the moisture from cell to cell, the kiln drying of lumber would present no more difficulty than the drying of wet cloth or clay. The problem would be merely one of conducting the requisite amount of heat to the material to supply that required for vaporization, which at 163° F. is 1000 British thermal units of latent heat plus a small additional amount (about 30 B.T.U. per pound of dry wood [3]) required to overcome the attraction of the hygroscopic material for the moisture. By use of a low pressure or a temperature higher than the boiling point the moisture would pass off directly in proportion to the quantity of heat supplied.

PROPERTIES OF THE WOOD WHICH AFFECT DRYING.

In the first place let us consider the physical properties of the material, which must be recognized in order to intelligently study the drying problem. Different species differ very greatly with respect to the relative proportions of these properties, but all possess them more or less.

1. The rate of transfusion of moisture through the wood substance has already been discussed. It is very slow in some woods, as oak, and fairly rapid in others, as pine. It is supposed that the rate is accelerated by increase in temperature.

2. Wood shrinks differently in different directions, and shrinkage usually begins only when the drying falls below the fibre saturation point, although with some species, as *Eucalyptus globulus* and some oaks, the point is not well defined.

3. Wood substance becomes soft and plastic at high temperature under moist conditions. The effect of temperature upon plasticity varies greatly with different species, some, as western red cedar, redwood, and eucalyptus, becoming excessively soft even as low as 150° or 170° F.

4. Cohesion between the fibres easily breaks down with increase in temperature in such woods as western larch, and the southern swamp oaks, thus permitting internal stresses to cause checking with great readiness.

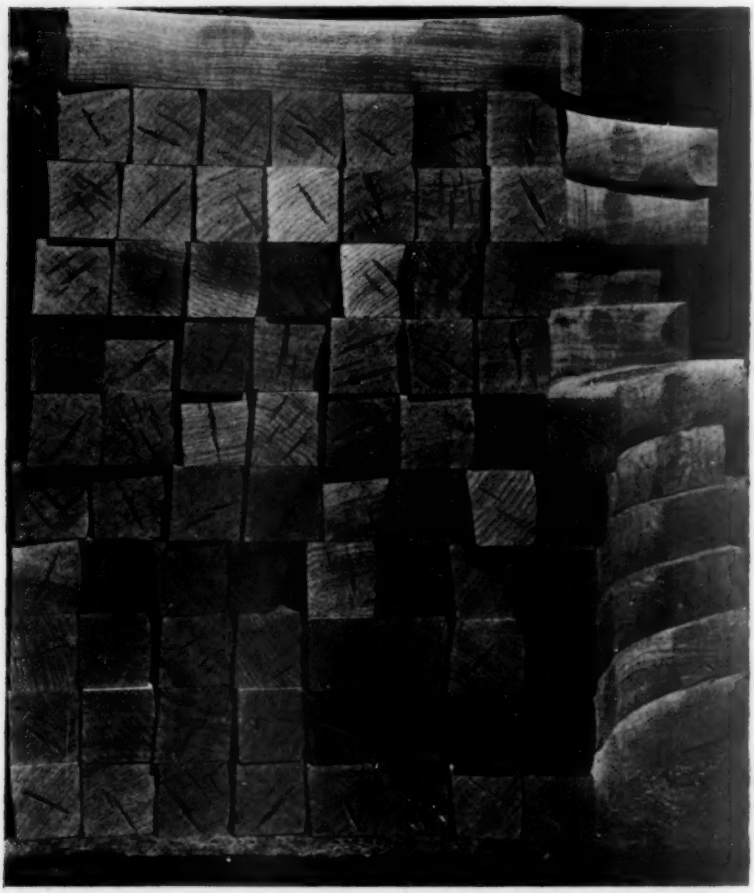
5. Tendency to warp is due to a warped direction of the fibres. Cupping of slab cut boards is simply explained by geometrical

[3] Frederick Dunlap, Forest Products Laboratory.

relations due to unequal shrinkage radially and circumferentially.

6. Wood shrinks more when dried slowly under moist conditions than when dried rapidly, and the higher the temperatures under moist conditions the greater the shrinkage.

FIG. 3.



Badly honey-combed oak wagon felloes. Produced by too severe casehardening in drying.

7. Excessive drying causes brittleness.

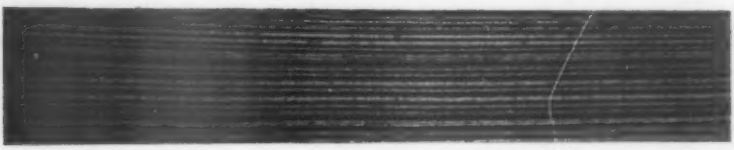
8. Wood absorbs or loses moisture in proportion to the relative humidity of the air, varying slightly according to the temperature. This property is known as "hydroscopicity."

9. Change of color occurs in some species in drying. This is distinct from sap stain or colors caused by fungus or bacteria. This is notable in hard maple sapwood and in sugar pine. In the maple, a moist warm atmosphere is conducive to this coloration.

10. Collapse of the cells may occur in some species while the wood is hot and moist. This collapse is distinct from the shrinkage which takes place in the wood substance and is due to a different cause.

These properties of the wood give rise to certain resultant internal stresses which are the main cause of warping, checking, and honey-combing (see Fig. 3). "Washboarding" is due to unequal shrinkage or collapse of adjacent layers of the annual

FIG. 4.



"Washboarding" in an inch board of blue gum (*Eucalyptus globulus*) due to the alternative collapse of the annual rings. This board was perfectly flat when placed in the kiln as is evidenced by the band saw marks running across the surface.

rings of wood and appears on radially sawed lumber (quarter-sawed). (Fig. 4.)

It is chiefly with the analysis of these internal stresses that this article has to do.

INTERNAL STRESSES AND "CASEHARDENING."

The term "casehardening" is used to describe the condition of wood which contains stresses brought about by drying. It is somewhat ambiguous but commonly used. As the derivation of the word implies, it signifies in general a hardened case on the outside of the wood—derived probably from analogy to the term as used in metal tempering where the outer surface of the iron casting is changed to steel. The analogy, however, is not a very good one and should not be followed too closely.

As applied to wood it is sometimes used to refer to two different, although interrelated conditions. One has to do with the moisture condition alone, and the other with the internal stresses resulting from the hardening of the fibres and the relative shrinkages. In both cases the wood contains internal stresses brought

about by unequal shrinkages and a stiffening of the fibres as the wood dries below its fibre saturation point.

A temporary condition of internal stress may be brought about merely by a difference in moisture content between the inside and the surface, which may entirely disappear when the moisture is equalized provided the fibres have not hardened unequally. Permanent stresses, on the other hand, may result from the unequal moisture distribution whenever the outer and inner fibres become set or hardened at different stages of shrinkage or under different stresses. In such cases the internal stress in the wood remains even after the moisture has been uniformly distributed. This condition is dependent upon the stresses which exist in the fibres at the time they reach their fibre saturation point and begin to harden or receive a " set " as it is termed.

There are four variable factors to consider which affect the result, namely: moisture content of the wood, degree of shrinkage, internal stress, and period at which the fibres become hardened or set. Moreover these factors are partly dependent one upon the other. Temperature is still another factor but may be treated as an independent variable.

When a piece of wet wood dries rapidly, the outer surface necessarily becomes considerably drier than the interior. Under ordinary conditions the outside dries considerably below its fibre saturation point while the interior of the wood is still in a green or wet condition. Normally wood begins to shrink at its fibre saturation point, but inasmuch as the interior of the block of wood has not undergone any shrinkage, the outer fibres are consequently held in what might be considered an abnormally distended condition. Inasmuch as the wood hardens or becomes stronger as soon as it dries below its fibre saturation point, these outer fibres may become hardened in this distended condition to such an extent that if this outer shell were now removed from the block of wood this shell would no longer shrink down to its normal condition. In other words, the outer fibres have thus become hardened or set in such a condition that they will not subsequently shrink the normal amount.

Let us again consider the block of wood in which the interior is still wet and the outer fibres have thus become set in this expanded condition. The outer fibres of the block are then in tension and the inner ones in compression. As the drying now

progresses the inner fibres subsequently begin to dry and will tend to shrink their normal amount. The inner fibres, however, are prevented in turn from shrinking their normal amount by the hardened, expanded condition of the outer case or shell. The result will be a reversal of stresses, the inner fibres now being thrown into a state of tension and the outer into a state of compression. Now, it may occur under certain conditions that the inner fibres will also harden in this somewhat expanded condition and the slight residual shrinkage of the outer fibres may be sufficient so that when the wood has become uniformly dry throughout, all of these stresses will disappear. The casehardening so produced is then of a temporary nature and disappears upon redistribution of the moisture. In the majority of cases, however, where rapid drying takes place, the inner fibres, when they harden up due to drying, remain in a state of tension and the outer fibres remain in a state of compression from the fact that the residual shrinkage of the outer fibres is not sufficient to relieve these stresses. Permanent casehardening therefore results. The question of whether casehardening is temporary or permanent is dependent upon the relative degree of hardening of the outer and inner fibres and the relative amounts of residual shrinkages when they become uniformly dry.

From a consideration of the stresses which occur during rapid drying of a piece of wood, it will be seen that the total shrinkage of the entire block will ordinarily be less in the case of the severely casehardened wood than it will be in the case of a block of wood where normal shrinkage of all of the fibres can take place.

It will also be observed that the first stages of casehardening, in which the outer fibres are in tension and the inner in compression, will tend to produce external checking if these stresses exceed the cohesion of the fibres. Secondly, after the reversal of stresses takes place the result will be that the internal fibres will tend to be pulled apart by the internal tensile stresses provided these exceed the cohesion of the fibres. The outer checks, if they have occurred, will consequently close up due to the compression stresses introduced in the external fibres by the subsequent shrinkage of the internal fibres. This condition of internal checking is commonly called "*honey-combing.*"

The analysis of the phenomena of casehardening is rendered complex, on account of interrelation of the four factors mentioned

above—moisture, shrinkage, stresses, and hardening—since all these variables must be considered at the same time. For this reason also the determination of the condition of wood with respect to casehardening is equally complex.

The method commonly used is to cut a thin disk across a stick of wood and slot this disk in the form of a tuning fork, but having, instead of two, a number of prongs. This slotted disk indicates, by the bending of the prongs, the condition of stresses existing at the time of cutting and also the residual shrinkages which may take place during the subsequent drying of the block. For example, let us consider a piece of green wood which is being rapidly dried and suppose the casehardening disk is cut at a period when the outer surface has just dried below its fibre saturation point and the interior is still green, the outer surface being in tension and the inner portion in compression. The prongs of such a disk will bend outwardly when cut on the saw, but when subsequently dried in an oven these prongs will reverse and bend inwardly, due to the fact that the outer fibre has already hardened somewhat in the expanded condition so that its normal shrinkage is less than the normal shrinkage of the inner side of the prongs.

Again suppose that a disk be cut at a period after the reversal of stresses when the outside is in compression and the inside in tension. Such a disk will immediately bend on the saw; that is to say, the outer prongs will tend to bend inwardly. Subsequent drying will only tend to increase the curvature.

It is apparent that there is a period somewhere between these two at which, if a disk be cut, the prongs will neither turn inwardly nor outwardly on the saw, but nevertheless they will subsequently turn inwardly when the disk is dried.

In introducing this subject the assumption was made that the stick of wood was rapidly dried. Ordinarily the more rapid the drying the greater is the casehardening effect. It will be evident that this is brought about entirely by the unequal moisture distribution during the drying of the stick of wood. Were it possible to extract the moisture from the interior of the block at the same rate that it is being extracted from the outer surface, casehardening would not occur either temporary or permanent. Furthermore it will be observed that the more rapid the drying rate, the greater will be the factors producing this condition.

These factors will therefore be reduced to a minimum by the slowest possible method of drying. Consequently, in very slow air drying of lumber, where the lumber is shielded from both winds and dry air, casehardening will be at a minimum, other things being equal. The reason for this is that in very slow air drying the differential in moisture distribution in a block of wood is very nearly equalized. There is not produced the excessive differential in moisture between the interior and the surface which is necessitated by any practicable process of enforced drying.

In kiln drying the aim is to retard the rate of surface drying by a high humidity in the surrounding medium in order to prevent the casehardening from becoming excessive at any time, but some casehardening is inevitable. The condition, however, can be relieved or even entirely reversed as shown in Fig. 8, by subjecting the wood to a high humidity and high temperature (steaming) for a brief time so that the hardened outer fibres are rendered soft and plastic and yield to the stresses.

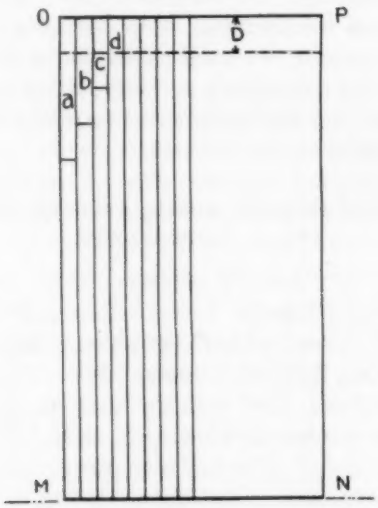
ANALYSIS OF STRESSES DURING PROGRESS OF DRYING AND OF CASEHARDENING.

In analyzing the internal stresses which occur during the progress of drying a square stick of wood, and the amounts of "setting" and shrinkage which take place, suppose that in Fig. 5, *o p m n* represents a disk cut transversely across the stick so that *mn* is the centre line. Let half the disk be assumed to be cut into 8 narrow strips numbered 1 to 8, strip 8 being next to the centre line of the disk. For convenience of conception, suppose that each strip consists of a spiral spring of equal strength attached to two horizontal bars *mn* and *op*, which are so arranged as to always remain parallel. Let the stresses produced in these springs be directly proportional to the amounts they are stretched or compressed from their neutral position. For the sake of the analogy drying of the wood is to be considered as equivalent to a shortening (not a compression) of the springs. This shortening may readily be accomplished by screwing up a nut on the lower end of each, the ends projecting through holes in the bar *mn*. If the springs are all independent, screwing up the nuts will merely shorten them an equivalent amount, but if they are all fast to the upper bar *op*, and only the outer springs are shortened, these will be stretched or placed in tension, pulling the bar downward and throwing those springs which have not been shortened

into a state of compression. This is exactly what occurs when the outer layers of a block of wood begin to dry below the fibre saturation point.

Notice now that if the springs be shortened one after another until all are finally shortened the same amount, the bar *op* will merely descend the same amount that the springs have been shortened and the stresses will disappear. This is what takes place in a piece of wood when dried without casehardening to a point where the moisture content is uniformly the same in each layer. This may be considered as *normal shrinkage* and is prob-

FIG. 5.



ably directly proportioned to the amount of hygroscopic moisture removed. Rarely if ever is this condition realized in drying anything but very thin material.

What generally happens is that the outer layer tends to shrink in drying but is considerably stretched by the resistance of the inner layers. Being a somewhat plastic material, it soon hardens in the stretched condition, so that it no longer tends to shrink the normal amount. Upon complete drying the inner layers will tend to shrink their normal amount, but will be slightly stretched (less so than was the outer layer), thus throwing the outer layer into compression and the inner layers into tension; they will also harden in their slightly stretched condition, but the stresses,

although less than they were at the first stages of drying, may remain in the wood. The wood is then permanently casehardened.

Going back to the analogy of the springs. When the outer spring has been shortened, say half the amount which would correspond to normal shrinkage, suppose it be annealed and rehardened, so that without altering its present stress, it then requires a greater force to stretch or compress it the same amount as before, and that approximately one-half of the total amount which it formerly might have been shortened (normal shrinkage) has already been removed. As the inner springs are then shortened in turn the outer "set" spring is thrown into compression and behaves very much as it would if it had been adjusted back again to its original length (as though it were resoaked in the case of wood), although this outer layer continues to be in a drier state than the inner layers. As a matter of fact the outer layer of wood not only acts as though starting again at its original length, but it has also become greatly stiffened at the same time. Here, however, the analysis becomes too complicated to follow clearly, and we will therefore disregard for the present the increase in stiffness which takes place in the drying of the various layers, and assume the springs to remain the same strength.

Having attempted to illustrate the behavior of the wood by the hypothetical analogy of the springs, let us follow the line of reasoning a few steps farther. For convenience of reference, let us assume each spring to be 100 inches long. Suppose the nut on No. 1 be screwed up 8 inches, it will be thrown into a state of tension which will accordingly bring the other seven springs into a state of compression. The whole bar *op* will then evidently be lowered one inch, thus compressing the seven springs each 1 inch and stretching No. 1 a total amount of 7 inches. This is what happens when the outer layer of a piece of wood dries below its fibre saturation point, while the interior still retains some free moisture. Now suppose that No. 1 becomes "set" in its shortened but expanded condition, that is to say, in this position it no longer exerts the tensile pull which it exerted before, but its stress is neutral at the 1 inch shortened position. The bar *op* will therefore rise sufficiently to bring about a balance of stresses and this will cause a new tension in No. 1 and new amount of compression in the rest; No. 1 is then neutral at 99 inches and not at 92 inches as when first shortened. In other words, the effect

of shortening it the 8 inches has been done away with and it now acts the same (disregarding its increased stiffness) as though it had originally been shortened by one inch. If detached from the bar it will remain 99 inches in length, and when the disk is completely dried (all springs shortened 21 inches), it cannot be shortened its normal amount, as the others will be. Assuming the normal shrinkage (total possible shortening of the bars) to be 21 inches, No. 1 having already been shortened 8 inches and being neutral at 99 inches, it can therefore be shortened only $(.99 \times 13) = 12.87$ inches. So in the final state, the seven springs will be 79 inches long and No. 1 will be $(99 - 12.87) = 86.13$ inches. (The total possible shortening of all springs from their original lengths having been assumed as 21 inches.)

In this way we may analyze the progressive conditions of the stresses in the eight springs and their corresponding shortenings, corresponding to the progress of drying of the wood from the outer surface inward and the successive casehardening of the outer layers, when first separated from the bars, and when finally shortened the complete amount representing a state of complete dryness after separation. To make this system of analysis clearer, let us follow a single case for an example. Let springs 1, 2, 3, 4 each be shortened respective amounts a, b, c, d, by screwing up nuts on their bottom ends, and let the rest remain the original length of 100 inches. Let D be the distance the bar op will descend (equals the shrinkage of the entire disk as a whole). Let n be a factor by which if the distance the spring is shortened be multiplied it will give the stress existing in that spring, and let negative signs indicate tension and plus signs compression. Then the following equation will represent the stresses in all of the springs:

$$(D-a)n + (D-b)n + (D-c)n + (D-d)n + 4(D-O) = O \quad (1)$$

Since the summation of all these stresses must equal zero

$$8D = a + b + c + d$$

Now we are at liberty to shorten each spring an assumed amount (corresponding to the degree of drying out of the successive layers). For instance, suppose

$$d = D,\ a = 3c,\ b = 2c$$

then the relationship of D and c may be calculated.

Substituting in the equation (1):

$$7D = 63,\ c = \frac{7}{6}D$$

Suppose $D = 6$ inches then

$c = 7$, $b = 14$ and $a = 21$ inches, and the stresses are No. $1 = 15n$ No. $2 = -8n$, No. $3 = -1n$, No. $4 = 0$ and each of the others $= +6n$.

Spring No. 4 having been shortened (shrunken) the same amount as the bar is lowered will neither be compressed nor elongated and will have no stress.

Suppose now that spring No. 1 be extended to its original length by unscrewing the nut on the bottom the full amount (swelling to its original condition by wetting in cold water or saturated air). The others remain shortened the same amounts as before.

Let D_1 be the new position assumed by the bar

$$8D_1 = 0 + 2c + c + d.\quad 8D_1 = 3c + D = 21 + 6 = 27.\quad D_1 = 3\ 3/8$$

No. 1	No. 2	No. 3	No. 4	Nos. 5, 6, 7, 8
$+3\ 3/8n$	$-10\ 5/8n$	$-3\ 5/8n$	$-2\ 5/8n$	$+4(3\ 3/8)n = 0$

The stress in No. 1 has changed to compression, and the tension in Nos. 2 and 3 has been increased and No. 4 has now been placed in tension.

Without following further the calculations in detail, the various relative stresses and the total shrinkages of the disk are set forth in Table I for several assumed progressive conditions of casehardening and reabsorption (neglecting the increased stiffening of the springs, as explained before).

The first column after "Conditions" gives the shrinkage of the disk as a whole in inches (a wholly conventional unit assumed for convenience of discussion) and the next eight columns show the relative stresses in each of the respective strips. They represent the actual stresses existing in the disk at the horizontal centre line *mn*. (In the unslotted disk the stresses decrease as the ends are approached, becoming zero at the end, due to the shearing stresses between the adjacent strips.)

A careful study of Table I will reveal many interesting facts and will explain the peculiar and apparently anomalous behavior of the prongs of the test disk when slotted at different periods of the drying and when cut into different thicknesses.

The progress of the stresses in the eight layers from the outer surface to the centre of the stick of wood during drying may be

TABLE I.

Stress Conditions During Progress of Casehardening.

Condition of Casehardening	Shrinkage of Disk, inches	Comparative Stress in Terms of Some Constant *n* Strip No.								Remarks
		1	2	3	4	5	6	7	8	
A. Strips 1 to 4 have dried, 5 to 8 still wet, equivalent to shortening *a*, 21; *b*, 14; *c*, 7; *d*–*D* inches.	6″	−15	−8	−1	0	+6	+6	+6	+6	Strip 4 is neither in tension nor compression.
B. Strip No. 1 is swelled to full length, others not altered.	+3 3/8″	+3 3/8	−10 3/8	−3 3/8	−2 3/8	+3 3/8	+3 3/8	+3 3/8	+3 3/8	Tension in 2, 3, 4 is increased but not as great as No. 1 in *A*. Compression in 5, 6, 7, 8, all decreased.
C. Strips No. 1 and No. 2 swelled to full length, others unaltered.	+1 5/8″	+1 5/8	+1 5/8	−5 3/8	−4 3/8	+1 5/8	+1 5/8	+1 5/8	+1 5/8	Tension of No. 3 increased but not as great as in *A*.
D. Strips Nos. 1, 2, and 3, swelled to full length, others unaltered.	3/4″	+3/4	+3/4	+3/4	−5 1/4	+3/4	+3/4	+3/4	+3/4	Strip 4 now carries the only tension.
E. Condition *A* resumed. No. 1 is then softened by steam so it offers no compression as it does in *B*.	+3 1/2	0	−10 1/2	−3 1/2	−2 1/2	−3 1/2	−3 1/2	−3 1/2	−3 1/2	Strips No. 2, 3, 4 are greatly increased in tension by this steaming.
F. No. 1 becomes "*set*" at the condition in *A* so that its normal length is now 6″ shorter than at first. All the others are shortened progressively, amounts No. 2, 21; No. 3, 19; No. 4, 17; No. 5, 15; No. 6, 13; No. 7, 11; No. 8, 10 inches.	+14″	+8	−7	−5	−3	−1	+1	+3	+4	This is the first evidence of true casehardening. After slotting and completely dried all the other strips will shrink 21″. No. 1 remaining at 6″ since it has previously been dried its full amount. See Case *A*.

TABLE I—*Continued*

G. Strips No. 1, 2, 3 become set in *A* equivalent to starting each with a normal length 6″ shorter than originally.	$+10\frac{1}{2}''$	$+4\frac{1}{2}$	$+4\frac{1}{2}$	$+4\frac{1}{2}$	$-6-\frac{1}{2}$	$-4\frac{1}{2}$	$-2\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	Second case in casehardening. When dried Nos. 4 to 8 shrink 21″ No. 1 remains 94 inches long since it shrinks no further being dry. No. 2 shrinks $6''+(21-14)\times.94''$; No. 3, $6''+(21-7)\times.94''$.
H. Strips 1, 2, 3 have become "set" but No. 1 in Case *A* with a shortening 6″ and 2 and 3 in Case F with a shortening of 14″. All the rest are assumed to be completely dry equivalent to shortening each one 21″.	$+17\frac{3}{8}''$	$+11\frac{3}{8}$	$+3\frac{3}{8}$	$+3\frac{3}{8}$	$-3\frac{5}{8}$	$-3\frac{5}{8}$	$-3\frac{5}{8}$	$-3\frac{5}{8}$	$-3\frac{5}{8}$	This represents the ultimate condition when uniformly dry. Note that total shrinkage of disk is only $17-\frac{3}{8}''$ instead of 21″.
	The final shrinkage when completely dry will be as follows:									
		6″	14″	14″+	21″	21″	21″	21″	21″	
I. Same as *H*, but strip No. 1 is then softened by steaming so as to remove all stress.	+19″	0	+5	$(21-19)+\frac{86''}{100}+5$	−2	−2	−2	−2	−2	Note the increased total shrinkage of disk.
J. Same as *I* but after steaming No. 1 shrinks its normal amount of 21″ the same as if it had not become casehardened.	$19\frac{1}{4}''$	$-1\frac{3}{4}$	$+5\frac{1}{4}$	$+5\frac{1}{4}$	$-1\frac{3}{4}$	$-1\frac{3}{4}$	$-1\frac{3}{4}$	$-1\frac{3}{4}$	$-1\frac{3}{4}$	This explains final reversal of casehardening. If slotted between No. 4 and No. 5 the prong will remain straight.

graphically indicated as in Figs. 6 and 7, in which tension is shown by distances below the horizontal lines and compression by distances above. This also shows relatively the lengths which the strips will assume if the disk be slotted at the condition under consideration. In the diagrams the combined area above the horizontal line always equals the area below.

Let us consider what happens in a few cases illustrated in Figs. 6 and 7.

If a disk be cut and slotted in Case A, the outer prongs will at once bend out on the saw, although no casehardening has yet occurred. If then dried slowly the prongs will become parallel again and of the same length.

In the Case B the outer prong will have a slight tendency to bend in on the saw, but if the disk be given a single cut through the centre the two prongs will bend outwardly on the saw. When subsequently dried, however, in both cases the prongs will bend inward. In Case F the same is true to a greater degree. In Case G, however, the prongs cut anywhere after the third strip will at once bind on the saw and will still further bind when finally dried. In Case H, if slotted up at any point, the outer prongs will at once bind on the saw, and remain so. The inner prongs 5 to 8, however, will remain straight.

If Case A be steamed at a low temperature or placed in cool, damp air, the outer portion will swell and offer a compression effort which will have the effect at first of increasing the tension on the inner layers, which is a bad effect as it tends to develop internal checking or cause external checks to run in deeper. Successive stages are shown in Cases B, C and D. Since the outer layer is not softened at the cool temperature, it will not intercrush (or crunch) under compression, and therefore no advantage is gained, since the same tendency to caseharden is again set up when it is dried again. If it be steamed, however, at a sufficiently high temperature to render it plastic, the outer layer will intercrush slightly as shown in Case E, and when further drying of the stick is resumed, it will not offer so great a resistance as it would formerly, as in Case H. Casehardening has thus been slightly reduced.

The most salubrious effect of steaming, however, is obtained after the Case F has been reached, and this reaches its maximum in the Case H. The effect of high temperature steaming is here

FIG. 6.

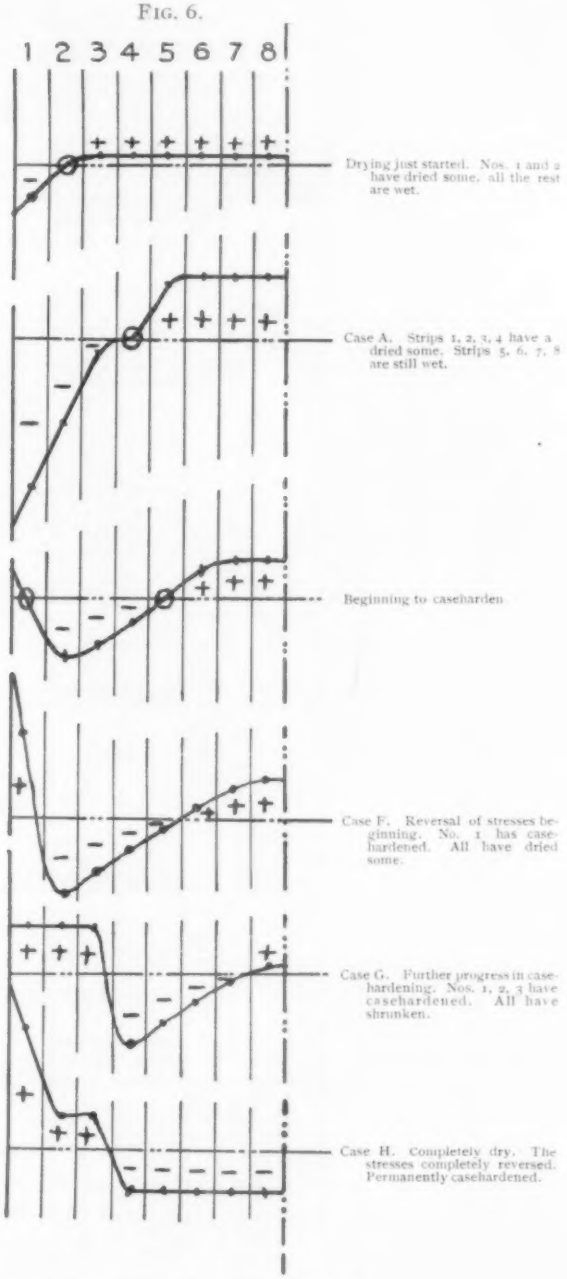

1 2 3 4 5 6 7 8
Drying just started. Nos. 1 and 2 have dried some, all the rest are wet.
Case A. Strips 1, 2, 3, 4 have a dried some. Strips 5, 6, 7, 8 are still wet.
Beginning to caseharden
Case F. Reversal of stresses beginning. No. 1 has casehardened. All have dried some.
Case G. Further progress in casehardening. Nos. 1, 2, 3 have casehardened. All have shrunken.
Case H. Completely dry. The stresses completely reversed. Permanently casehardened.

Diagram showing stresses in wood while drying.

FIG. 7.

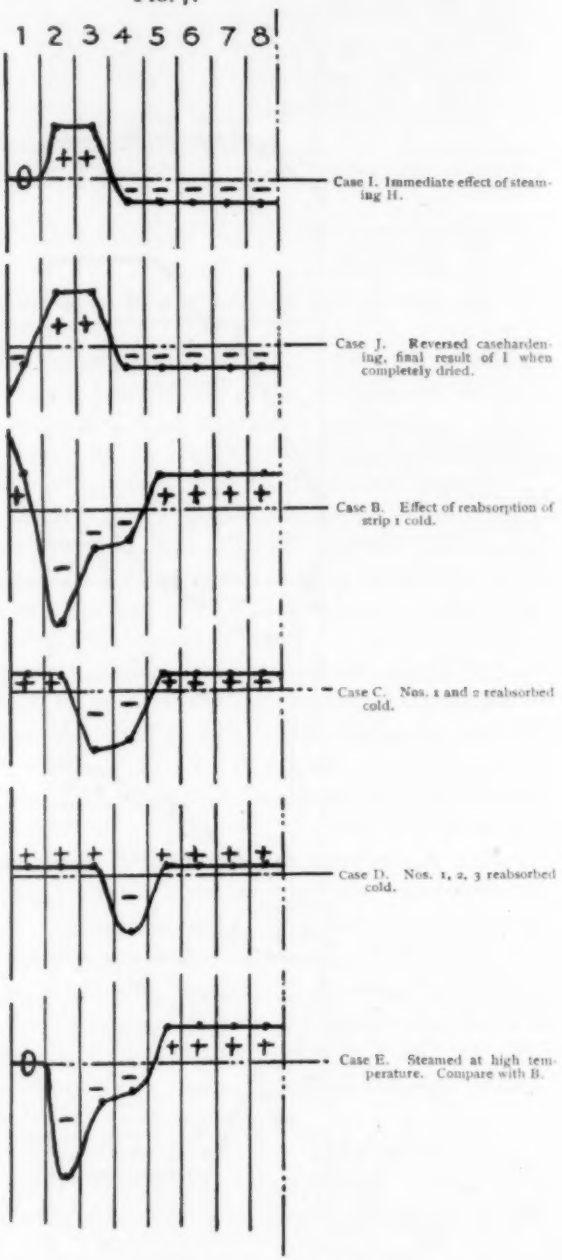
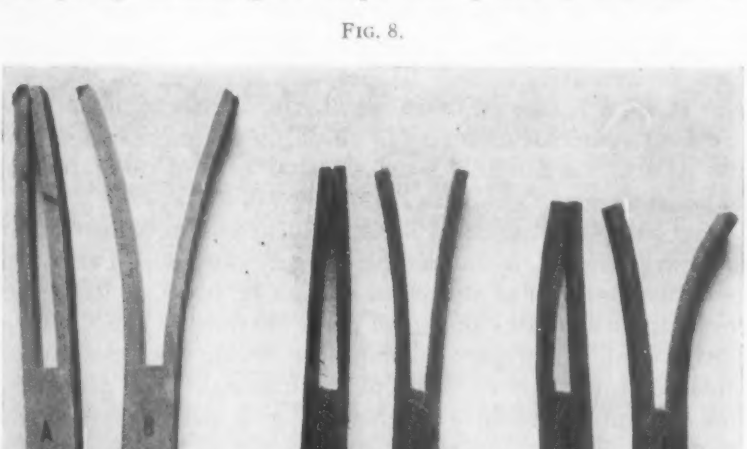

1 2 3 4 5 6 7 8
Case I. Immediate effect of steaming H.
Case J. Reversed casehardening, final result of I when completely dried.
Case B. Effect of reabsorption of strip 1 cold.
Case C. Nos. 1 and 2 reabsorbed cold.
Case D. Nos. 1, 2, 3 reabsorbed cold.
Case E. Steamed at high temperature. Compare with B.

Diagram showing stresses in wood while drying.
(Continued from Figure 6.)

to completely eliminate the compression stress in the layers affected, as is illustrated in the single Case I. The ultimate result, however, provided the effect has not penetrated to all layers under compression stresses, will inevitably be a reversal of caseharden-ing, shown in Case J. In this case, if the disk be slotted between 2 and 3, the outer prong will turn out slightly on the saw in Case I, and much more so in Case J. On the other hand, the next prong, consisting of strips Nos. 3 and 4, will still turn

FIG. 8.



Discs cut from casehardened maple and oak boards. The alternate ones on the left show the condition of the boards when first dried; those on the right show reversal of stresses brought about by steaming the same boards at a slight pressure.

inward, the same as in Case H. If sawed in the middle, however, there is much less cupping in J than in H; in fact, it might easily be that the stresses are balanced so there would be no cupping at all of the half-disk.

If the effect of the steaming be sufficient to penetrate all the layers under compression, all stress may be removed thereby.

While the cases chosen for illustration are largely empirical, and actual conditions will vary therefrom not only in relative intensities but in distribution, it seems probable that the maximum total stresses are very apt to occur in the first stages of drying as in Case A. The tension inside the block is at no time as

intense as on the surface. It may be that honey-combing starts initially with a small surface crack, which then follows inwardly as the wave of tension moves to the centre, somewhat in the manner that a crack in a pane of glass will follow the progress of a comparatively slight stress, much less than that which would be necessary to initiate the crack in the unbroken piece. If this is the case, cold reabsorption or steaming at a low temperature, before true casehardening has taken place to a considerable extent, is of no advantage but positively detrimental, as such treatment is here shown to intensify the tension in the adjacent layers progressively. High temperature steaming, on the other hand (Case E), may be beneficial in relieving the ultimate case-hardening (external compression effect) at the stage indicated in Case A, and it is certainly beneficial after decided casehardening has taken place at Cases F and H.

For aeroplanes, unequal moisture distribution, which means temporary stresses, is undesirable for any purpose. Permanent casehardening, such as illustrated in Case H, is not of itself very serious for wingbeams and small parts provided it is not severe; it may, however, presage an improper drying treatment which would be ground for rejection of the material. For propellers, however, any appreciable casehardening is detrimental as the internal residual stresses may cause changes to take place in the shape of the finished parts. Moreover, these stresses may change with time, which may introduce unknown stresses in the blades or tend to shear the glue joints. Or they may even cause checking or internal cracking to take place at some future time.

Shock-proof Tungsten Lamp. ANON. (*Scientific American*, vol. cxx, No. 25, p. 649, June 21, 1919.)—Despite the many improvements introduced in the manufacture of tungsten lamps, they have remained delicate until the present. There was a time, of course, when tungsten lamps had to be handled with extreme care to avoid jarring and shattering the delicate filament; but in more recent times the tungsten lamps have come to be fairly rugged and available for almost all purposes save in mills, printing plants, and other places subject to intense pounding or shocks. It has remained for one of our leading electric lamp manufacturers to introduce a new type of tungsten lamp which incorporates a shock-absorbing feature. The filament mounting, instead of forming an integral part of the glass stem as is usually the case, is spring-supported. This feature makes this lamp serviceable and preferable under almost all conditions where carbon lamps have been used heretofore.

INDUSTRIAL LIGHTING.*

BY

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If every working man in the industries of this country lost one minute per eight-hour day, each day, due to inadequate working facilities, the economic loss to the country, based on certain statistics, might approximately be set down as equal to $10,000,000 per annum. Similarly, a loss of one hour per day by the total employees in all industries would mean roughly a loss well on toward a half billion dollars per annum. These figures are based on the estimated wages in this country per annum as reduced to the total wages per minute or per hour, these factors then being employed as a basis for the determination of the losses just mentioned.

Reference will be made later to losses due to poor light and, conversely, to gains made possible by highly adequate light, and when the loss of a minute or an hour per day due to poor light is mentioned, while it may seem trivial in itself, its importance to the industrial economy of the country will be more evident from the foregoing general figures, while its relatively large magnitude when compared to the costs of the best lighting will appear subsequently.

DEVELOPMENTS IN GAS AND ELECTRIC LIGHTING CONTRASTED.

Those who have followed the developments in electric and gas lighting during the past years have probably been impressed by the apparent rivalry between the manufacturers of gas and electric lamps and appliances. This rivalry may, it is true, be only apparent, but it is interesting as throwing into relief some of the possible influences back of the rapid developments in these two fields. Gas lighting, as the older of the two, was employed in about the same way in the form of the old fish-tail burners for a number of years with little or no attention to reflectors or the scientific distribution of the light. Later, the

* Presented at a joint meeting of the Section of Physics and Chemistry and the Philadelphia Section, Illuminating Engineering Society, held Thursday, February 6, 1919.

electric lamp appeared and the many developments in electric lamp efficiency and in the effective use of the light from such sources, has been paralleled by similar developments in gas lamps and in auxiliaries for the highly efficient utilization of the light from these sources.

In somewhat the same manner the developments in the means for securing light in factory buildings has witnessed a contrast between natural and artificial illumination. There may or may not have been an actual rivalry between building constructors, on the one hand, in the design of windows and monitors for admitting daylight, and those who have been responsible for effective artificial lighting on the other hand, but the past ten to fifteen years have witnessed marked advances in both of these fields. Not only has there been an awakening to the needs of the case but new methods and new types of artificial lighting equipment have been applied to industrial buildings in recent years and along with them has come a higher appreciation for buildings so designed as to admit plenty of daylight and in such directions as to reach the working surfaces effectively. In what follows, it is the intention to dwell to some extent on both of these phases of industrial lighting, partly by way of pointing to individual characteristics of the illumination from both natural and artificial sources, and to some extent in contrasting the two.

SOME CAUSES FOR POOR LIGHTING IN EARLIER PRACTICE.

It might seem at a first glance that the importance of the best form of illumination for industrial processes is so fundamental and obvious that there would be little or no need to emphasize the relations of good lighting to effective and accurate workmanship. The widespread neglect of such facilities indicates, however, that lighting is one of those things in the factory equipment which can readily be overlooked and concerning which there is still much ignorance on the part of industrial managers and shop owners. These conditions make it necessary to dwell repeatedly upon such things as the value of good light to production, and also upon the physical means now available for the accomplishment of successful illumination at the working surfaces in the industries.

Going back fifteen to twenty years, the inadequate illumination in many older industries may easily have been the result not

so much of neglect, as of an inability to secure suitable lamps. The older arc lamps, representative of the larger sizes, and the carbon filament lamps, of the smaller sizes, each had their own limitations for the attainment of success in factory lighting. Large lamps were not adapted to low ceilings and the apparent difficulties in the way of providing general and uniform illumination over the entire floor areas where high ceilings existed, either with arc lamps or with groups of small carbon filament lamps, often made localized lighting the logical result in earlier practice. Intermediate ceilings, falling between low and high clearances, constituted an unusually large proportion of some factory areas, and such locations, in earlier practice, sometimes presented greater difficulties from the viewpoint of general illumination, than either the low or the high spaces.

The successful use of tungsten and of mercury vapor lamps for factory lighting purposes marked a new era in this field of artificial illumination and solved many problems which previously had been difficult to handle with the very limited lamp sizes in the arc and the carbon filament types. In fact, the very obvious advantages of a lamp of medium size, whether tungsten or mercury vapor, are so great in the successful illumination of many factory spaces, that it is an open question whether the recent development of nitrogen-filled lamps with very high efficiencies in the large lamp sizes is an advance equal to the appearance some fifteen years ago of the older tungsten lamps in medium sizes, at least so far as the industrial lighting field is concerned. In other words, it may be found desirable to illuminate many factory interiors with less efficient tungsten lamps of the intermediate sizes so as to secure better distribution of the light through the larger number of units thus required than to adopt the larger lamp sizes merely to obtain a unit with a higher candle-power per watt rating.

REASONS FOR DEVELOPMENTS IN FACTORY LIGHTING PRACTICE.

In spite of the widespread neglect of the ideas of good lighting in many industries, there has been a notable development in the way of better lighting among the plants of the more progressive class during the immediate past. This development may be ascribed to the newer types of lamps and to more carefully designed reflectors, with the possibilities for the highly effective

lighting results they have made available, but other factors have doubtless contributed to this development. One of these perhaps has been the ideas back of scientific management and the higher appreciation which these ideas have emphasized for a favorable working environment for employees. The advantages of good working facilities, of which lighting is a type, have come to be looked upon in recent years as tangible and very real factors in the successful management of American industries, and additional attention has been directed toward this phase of the subject by the stress of the recent war emergency, which will be referred to again later on.

Another influence which has undoubtedly been back of these developments in factory lighting is the keen interest which has been taken in the subject by lamp and reflector manufacturers. Aside from any commercial considerations, this active and painstaking work by the manufacturers has been such as to merit the approval of all of us who view the problem from just as interested although a less commercial point of view. The need for continuously keeping these high ideals in mind on the part of the lamp and reflector manufacturers is, however, increasingly great because of the effect upon any industry of the law of supply and demand. People generally to-day confuse good lighting with extremes in glare and brilliancy from high candle-power lamps. For reflector and fixture manufacturers to give way to this popular prejudice favoring brilliancy of lighting units would be a step backward, and it is to be hoped that light users may in time be educated up to that point where they will appreciate good illumination and the freedom from glare in such a measure as to supply the necessary commercial demand for equipment which meets these primary requirements in good lighting practice. It is hardly necessary to add that the industrial field is one of the important cases where these comments apply very generally.

Finally, as a fourth cause for the increasing attention to better lighting in recent years, there may be mentioned the slowly growing emphasis which is being placed upon the subject by state labor departments through codes and other legislative enactments covering industrial lighting. These state regulations, although drafted primarily with the view of safeguarding employees through better lighting, and hence not directing attention to any extent to the economic advantages of good light, except perhaps

indirectly, have undoubtedly become quite a potential factor in this field. Some of the developments in state codes will be referred to later.

RULE OF THUMB VERSUS EXPERT METHODS.

To the popular mind, the duties of the industrial lighting engineer probably consist merely in the choice of lamps and in hanging these lamps at certain locations. In fact, the actual conduct of industrial lighting design, or planning, as it might more properly be termed, by many architects and others, depends to such an extent upon rule of thumb methods, that such a conclusion may be valid when referred to such methods. The design of a truly successful factory lighting system, however, often presents peculiarities and special problems which merit individual attention not only to given sections of the plant from the standpoint of the kinds of work conducted, but sometimes to the particular needs of individual workmen. Hence, it is apparent that the whole subject can either be looked upon, on the one hand, as one susceptible to solutions by rule of thumb methods, or, on the other hand, as one in which highly specialized talent can well be utilized by the plant management.

To my own mind, the latter method is the best if not the only safe course to follow. Eyesight is too valuable an asset to the millions of wage earners of this country, and also to the economic interests of industry, to neglect the light under which vision must function in seeing such an infinitely wide variety of industrial operations, where the personal element combines, under both physiological and psychological influences, to still further complicate the problem. Therefore, merely from the standpoint of providing illumination which is correct both in quality and quantity, expert assistance is warranted in the making of such plans. Moreover, there is a wider aspect of the matter, and to give a general idea of the variety of additional problems which the industrial illuminating engineer may be called upon to handle, it may be in place to enumerate very briefly several items which have constituted a part of his duties under actual working conditions.

ITEMS CLOSELY ALLIED TO INDUSTRIAL LIGHTING.

These include such things as the study of distribution circuits and transformer capacities for the supply of constant voltage to the factory lamps, the study of the proportion of motor load to lighting load on given circuits, in its relation to voltage variations

on the lighting part of such combined loads, and the factors involved in the possible subsequent recommendation that such combined loads on a given circuit be separated. Again, in one factory I recall steps that were taken to establish the minimum voltages to apply to given rated lamps for the maintenance of approximately white light. Other important items have been the establishment of proper lamp arrangements and suitable intensities for each class of work and for each location, such as the office, the drafting room, the foundry and the machine shop. Maintenance work must be standardized, since no industrial lighting system can be expected to keep up to its original excellence unless lamps and reflectors are cleaned, and burned out lamps are renewed regularly and promptly.

Many other problems may present themselves, such as the prevention or, at least, the reduction of theft of lamps in the large factory; campaigns among the superintendents and the employees looking towards the intelligent economy of light; the prevention of polarity reversal on direct current circuits, where such a reversal may cause instant injury to given types of lamps; the large question of voltage drop in the distributing circuits, which may sometimes include the factor of mutual inductance where lamps are supplied from two phase alternating current power mains. Then there is the important point of the most economical method for producing a given quantity of illumination at the working surfaces, which includes such factors as light walls and ceilings; also the selection of those types of reflectors, whether glass or metal, most suitable for factory conditions, and at the same time capable of increasing the proportion of the total light from the lamps which reaches the working surfaces; the study of the effects of good light upon rates of production and upon accuracy of workmanship; the methods of wiring best suited to the various types of factory building construction; the best ways to provide light for stairways and passageways and the relations of such light to accident prevention; the very special study of particular cases and operations where unusual requirements are imposed upon vision; the relative advantages of clear and of translucent glass for factory windows from the illumination standpoint; color effects upon various kinds of material, important in textile establishments and sometimes in such special cases as the assortment of metals like copper, brass and iron with their characteristic differences in color.

RESPONSIBILITY OF THE SHOP ELECTRICAL DEPARTMENT.

Problems of peculiar interests, and sometimes correspondingly difficult, arise from time to time in such work, and among these is that of the proper illumination of the instruments on the switchboards of the shop power-house, or the faces of time-clocks located overhead in the aisles of some factories, the illumination of boiler-room gauges, and of coal bunkers, and that fundamental problem of providing enough of a side component in the resulting illumination properly to light vertical or side surfaces of the work.

It is readily recognized that many of the foregoing items which may confront the industrial lighting engineer have received sufficient attention during the past few years to have become in a way standardized. Furthermore, some of the things mentioned may, in certain cases, fall under the jurisdiction of other departments of the plant. The list is given, however, to show that industrial lighting constitutes a problem of fairly broad possibilities, and that it touches a variety of the items which go to make up the shop equipment. Perhaps the close alliance of shop lighting with so many divisions of the factory equipment may be one of the reasons why it is neglected or overlooked, through the assignment of the lighting problem to the care of a factory foreman or superintendent in charge of the electrical department or possibly of the power-house and distributing circuits as well as the motors and general power conditions, with so many interests that there is little time available for specialized study of the lighting conditions and their effect upon vision and upon production. However, there is this compensation even where such conditions exist, that the shop man directly concerned with the supervision of the lighting, although often entirely incapable at the outset, through ignorance of the principles involved, of successfully handling the problem, will often be found most receptive when suggestions are made and often develops an aptitude for the work which enables him to handle it very effectively.

THE PERSONAL EQUATION AMONG EMPLOYEES.

The matter of supplying light for the employees of an industry is thus complicated by the infinite variety of operations and the kinds of things pertaining to the work handled in the various classes of establishments, which make it utterly impossible to assign rules, for the simple reason that while they may perhaps

be adaptable to one kind of work, they may at the same time be entirely inadequate for another. Moreover, the illumination of a piece of work is not only a matter of furnishing so and so many units of illumination intensity upon that work, but its effect in rendering the work visible will be governed very largely by physiological and psychological characteristics of the workman himself. It is not surprising, therefore, to find a person dissatisfied with an ideal lighting system, not because of any difficulties in seeing the objects illuminated, but because the lamps "are too high," or "the quality of the light is too cold," or "the bowls of the lighting fixture are too dim."

On the very face of it, therefore, where light must be furnished to many employees in large office or shop sections, it is almost fundamental to the successful handling of the problem first, to know what is the right and proper method to adopt and then to adhere to this in spite of criticism on the part of employees until such time as the system has been given a fair trial, and individual rather than collective comments can be sifted out. When this time arrives, say after a month of trial for the new system, then individual complaints can well be investigated and, where necessary, remedied.

In this connection, I have seen large factory sections where individual lamps were depended upon solely for the light, and where a new system of general illumination with overhead lamps was about to be installed, when the foremen and superintendents foresaw a distinct need for the retention of the local lamps close to the work. A general complaint in advance of the new installation was forestalled by the simple expedient of agreeing to remove all drop lamps at the time the new system went into effect under the condition that those drop lamps which might be called for after, say a six weeks' trial of the new system, would be reinstalled if found actually necessary. The success of such an expedient can be very gratifying to those responsible for the new system, if the new system is really a superior one, but the designing engineer should never be so sure of himself as to neglect proper attention to individual complaints, which are often entirely justified by special circumstances. It is a cause for regret that there is a notable tendency to turn down such complaints after a new system is installed which the proprietors consider first-class, and I have run across cases of this kind where such a policy

worked a real hardship upon certain employees, for whose work the new system did not meet the needs for good vision.

PHYSICAL ASPECTS OF THE PROBLEM.

To these subtle physiological and psychological factors there must be added the physical part of the problem, which is concerned with such things as the surroundings of the location to be lighted, the class of things to be seen, the intensities of illumination to provide, and the types of lamps and of reflectors to use and their suitable arrangement. To take all of these factors into account obviously calls for the assistance of specialists in a number of fields, and, conversely, thus indicates why those interested in illumination constitute such an exceedingly wide variety of professions. The personnel of the membership of the Illuminating Engineering Society is a reflection of this interesting feature, and the presence in its membership lists of physicians, ophthalmologists and psychologists, as well as of physicists and engineers, is an index to the ramifications of the field.

Turning now, however, to some of the effects of surroundings and of working conditions generally upon the industries as a whole, we find, first, that light holds an important place in what may be termed the factors which determine the character of the shop environment; and second, that light, as one of the factors, is closely related to the employee through its effect on his ability to see clearly, and thus, in turn, to the production rate, to the amount of defective workmanship, and to the likelihood of accidents.

INDUSTRIAL LIGHTING AND THE WAR INDUSTRIES.

This close relationship between good and bad light, as the case may be, and the welfare of the employee, together with what has seemed for years to be a more or less close relationship between good light and normally rapid production, between good light and better workmanship, and between good light and a low accident rate, may be taken as an indication of why the question of highly adequate light for the industries was looked upon during the recent war as an item of fundamental importance to war work. In fact, one of the departments of the War Industries Board, known as the Employment Management Division, committed itself during the past year, prior to the signing of the armistice, to the preparation of instruction courses, for employment managers

throughout the country, which contained plans for advancing the ideas of such men, by intensive instruction, in the relations of just such factors to the employee, to production and to the accident rate.

This is a significant point. To aid the industries under the pressure of a war emergency, natural and artificial lighting were considered an important part of an intensive war program. The campaign to gather information for these purposes last year forms an interesting commentary upon the necessities and urgency of work under the pressure of war needs. It was my own privilege to gather a large amount of data for the Employment Management Division of the War Industries Board, at its suggestion and by its authority, on natural and artificial lighting last year before the close of the war, and the cessation of hostilities has led this Division to place at my disposal practically all of the files of data and other information thus accumulated, so that I am privileged in a part of what follows to comment on certain interesting points and on some conclusions based on the information gathered during the past year as a part of the war program.[1]

RELATIONS OF GOOD LIGHT TO PRODUCTION.

The exact relations of good light to industrial management are important for several reasons. First, and perhaps foremost, is the necessity of convincing the factory manager that the expenditure for a highly adequate system is warranted by the effects it is likely to have upon the management of his employees; and second, in the assurance which such relations give to the industrial lighting engineer or salesman that his efforts to raise the standards of factory lighting are warranted by the results. These relations of good light to management have been expressed in a variety of ways on a basis of the more or less obvious effects it is likely to have on increased production for the same labor cost in a plant, in the greater accuracy of the workmanship in the well-lighted shop, in the reduced accident hazard, in the avoidance or the minimizing of eye strain, and the healthy reaction upon the working force due to the more cheerful surroundings and the more comfortable conditions afforded by the light *versus* the gloomy interior. Adequate general illumination also removes

[1] The Employment Management Division of the War Industries Board now forms a part of the Federal Board for Vocational Education.

dark corners, and it is commonly observed that such a shop is likely to be kept cleaner than companion spaces which are relatively dark. Greater attention to janitor service promotes neatness on the part of the employees and thus tends to raise the tone of the plant.

These advantages of good light are all valuable as showing its importance to any plant and they have often formed the basis for decisions to install better lighting in places formerly very poorly illuminated. However, to say that good light promotes production and reduces accidents is a qualitative statement. The average shop manager is receptive to such ideas; but, in themselves, such abstract statements are difficult to translate into actual returns for the expenditure involved and hence lack the definite characteristics which would so often convince the manager that his judgment concerning the need of a new lighting system is correct.

ANALYSIS OF LIGHTING COSTS.

One of the first steps towards a more definite basis for setting forth the advantages of good shop lighting was the now well-known type of analysis suggested by Chas. F. Scott in an editorial in the *Electric Journal* in May, 1910, in which he emphasizes a new viewpoint in the consideration of industrial lighting, by suggesting that the cost per day for the best lighting system in a given factory section may conveniently be evaluated to the equivalent wages per day in that same section. At a first glance it does not appear just what such an evaluation may amount to, but since Professor Scott's suggestions in 1910, this relationship has commonly been found to be on the order of two to six minutes. In other words, the entire cost for lighting a shop section per day will usually be found to be the equivalent of the wages in that section for several minutes of the entire working day.

The foregoing figure has often proved to be most conclusive in the survey of an old system and one which has been entirely inadequate, because of the relative ease with which time losses due to inadequate light may be observed by inspection of the shop and by inquiries of the foremen and others in charge. Any shop section, therefore, in which time losses of, say a half an hour per day, occur because of poor light, should obviously reap quite a reward by the adoption of a new and improved system at a cost for operation of one-sixth of the daily loss in wages due to the old system.

EXPERT OPINIONS ON THE LIGHTING NEEDS OF THE INDUSTRIES.

This form of analysis, coupled with personal investigations in the field, have long been used as the basis for the commonly accepted idea that good lighting aids factory production, and that the average lighting conditions in the industries could well be raised to standards considerably in excess of present values. In fact, during the past year, that is to say, before the close of the war, a canvass was made among leading illumination experts in this country [2] to ascertain by how much industrial lighting ought to have been adjusted or changed from standards existing before the war in view of the fuel shortage and of the war, with the result that opinions favored an increase of 50 per cent. in industrial lighting in spite of an opinion that it ought to be decreased in every other branch of the lighting field, such as street, public building and commercial lighting. The figure of 50 per cent. increase appears to have been a conservative opinion because of the opinion of these same experts that without regard to the war conditions and the recent fuel shortage, industrial lighting standards could well be increased by 175 per cent. These opinions, it will be noted, favored marked increases in the quantity of light used for factory operations.

Now the codes of lighting recently issued by the several states who have given this matter special attention, contain tables of the quantities of light as a minimum and as desirable for given classes of work. These quantities have been based on the objective feature of safeguarding the workmen. They have not been based directly on the values desirable from the standpoint of maximum production at the least labor expense, for the simple reason that the state departments of labor are primarily concerned in regulations for the protection of labor, physically speaking. If a table of quantities of light for various classes of work were to be prepared on the basis of the most favorable production rates, there would be a strong tendency materially to increase the values found in these state lighting codes. In the past the magnitude of the increases in the quantities of light over and above the minimum values required by considerations of safety to the eyesight of employees and as a safeguard against accidents, has

[2] Paper on "Lighting Curtailment," by Preston S. Millar, Trans. Illuminating Engineering Society, Vol. xiii, No. 2, p. 126.

largely been based on individual experiences in various cases. To a large extent this condition prevails also at the present time.

RECENT TESTS ON LIGHTING AND PRODUCTION RATES.

To ascertain the desirable quantities of light to use on a basis of production rates calls for study of the rates of production under different quantities of light ranging from lower to higher values, keeping all other factors in the management of the plant as nearly unchanged in the given section as possible while the investigations are under way. Obviously, this is a task of considerable difficulty and data of this nature have been slow to materialize. Reports [3] on tests in a number of plants in the Chicago district show what appears to be an interesting relation between the production rate and the intensity of illumination provided at the work. In one plant, for example, increases in production of 8 to 27 per cent. in various operations followed an increase in the intensity of illumination from 4 to 12 foot-candles, the lower and higher values having been in use for two consecutive months. These figures tend to verify the close relationship existing between adequate light and the rate of work, and the figures just quoted also contain the further interesting commentary on costs of light in that a general figure is given in the report that by the expenditure for better lighting of about 5 per cent. of the pay roll in a plant section, a 15 per cent. increase in production can usually be secured, this conclusion being based on the above and other tests in the Chicago district.

RELATIONS OF GOOD LIGHT TO ACCIDENTS.

The above relations of good light to production contain the basis for much help in the education of shop management up to a higher appreciation of the advantages of such facilities. There is, however, the other important aspect of light as a factor in industrial accidents. For adequate data on this phase of the subject we may turn profitably to the Casualty Insurance Companies, because their interests are intimately connected with accident prevention, and if lighting is a material factor, it would naturally be one of the items of the shop equipment to engage the attention of such casualty companies.

From such sources reports from time to time have shown

[3] A Paper on "Productive Intensities," by Wm. A. Durgin, Trans. Illuminating Engineering Society, Vol. xiii, No. 8, p. 421.

that the industrial accident rate in this country is influenced to quite an extent by improper or inadequate light. In fact, the extent of this influence has been expressed as equal to about 18 per cent. at the present time; that is to say, about 18 per cent. of all industrial accidents are said to be due directly or indirectly to poor, or what may be termed defective, lighting conditions.[4] This may be interpreted as the quivalent of so much labor loss per annum and estimates place this loss as the equivalent of removing about 100,000 workmen from American industries for an entire year each year. The similar estimate for the labor loss due to accidents from all causes has been set as the equivalent of removing about 600,000 men for an entire year each year, so that the loss due to poor light is seen to be about one-sixth of the total. In 1910 the per cent. of total industrial accidents chargeable to poor light, directly or indirectly, was set at about 24 per cent., although the investigation of the records of the particular Casualty Insurance Co., on which the figure was based, resulted in a figure of about 10 per cent. in 1910 for the accidents due primarily to poor light, whereas the remaining 14 per cent. represented cases where poor lighting was merely a contributory cause.[5] Apparently the figure of about 24 per cent. for 1910 may be compared roughly with the more recent figure of 18 per cent. for 1918, on the basis of which the conditions seem to have improved slightly in the eight-year interval.

HIGH ACCIDENT RATE IN WINTER MONTHS.

An interesting conclusion has been drawn from the well-known curves of Mr. John Calder, first published in the Transactions of the American Society of Mechanical Engineers, as showing the increase in the number of accidents in the industries which are fatal for that part of the year in which normal day hours from 7 A.M. to 6 P.M. are partially dark. This conclusion[6] indicates that the number of accidents in the months of December and January are usually greater than the number that would be expected from the curves if the same amount of light (daylight)

[4] A Paper on "The Relation of Light Curtailment and Accidents," by R. E. Simpson, Trans. Illuminating Engineering Society, Vol. xiii, No. 8, p. 431.

[5] A Paper on "Illumination and One Year's Accidents," by R. E. Simpson, Trans. Illuminating Engineering Society, Vol. x, No. 9, p. 870.

[6] See reference given in footnote 5, p. 869.

existed in winter as in summer. In fact, the increase based on the given curves has been set at 40 per cent.

To the foregoing figures there might be added many convincing descriptions of specific cases where poor lighting has been the primary cause of accidents, both fatal and less serious, as compiled from the experiences of the Casualty Insurance Companies, and these would tend to confirm the general conclusions just mentioned concerning the relation between light and industrial safety. The fact that poor light is a large factor in accident hazard has probably been covered sufficiently, however, to indicate why state labor departments have begun to include lighting regulations among their industrial rules as one of the important factors in the whole campaign of accident prevention and the safeguarding of the life and limb of industrial employees.

ENGINEERING DETAILS OF NATURAL LIGHTING.

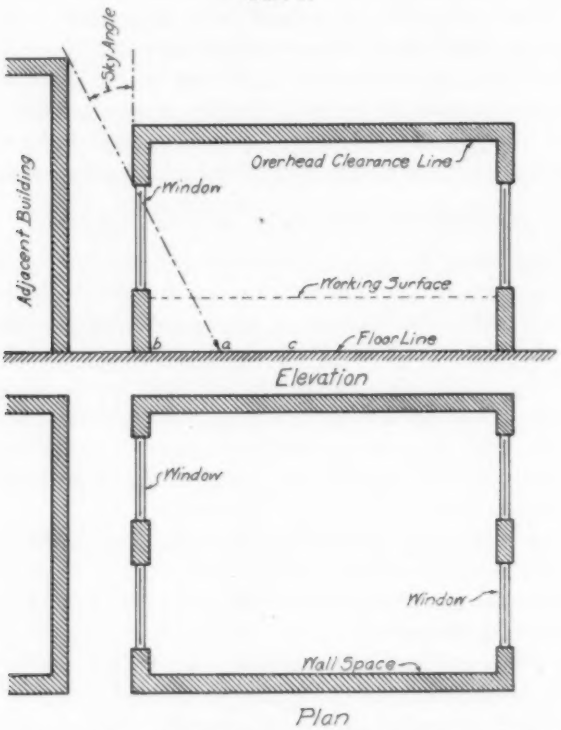
The engineering details involved in planning for natural lighting facilities are fundamentally more difficult than those for artificial illumination because of the extremely variable nature of the daylight throughout given days and for the same hour of the day at different times of the year. Furthermore, many factors, such as the use of side windows which supply natural light in a manner not symmetrical to the floor space, and the presence of nearby structures to impede the light, make it very difficult to assign definite rules for daylight planning.

The general trend of development in the desgin of modern factory buildings has been to employ larger and larger proportions of window space, until extremes have been reached in some cases and the natural illumination has been made excessive and uncomfortable to the employees housed in such structures. Architects and other factory construction designers tend to work towards constants such as certain ratios of window area to floor area in their plans, and this can be made a good basis, provided such constants are used with due regard to the fundamental points involved. Without using proper care in the application of such constants, window planning reduces to little more than a rule of thumb calculation, and the results may be good or bad, depending on the nature of the factors which surround the structure.

To illustrate the attitude taken towards the use of such constants it may be in place to mention a very caustic letter which I received some time ago from a party interested in the problem

of reducing structural daylight plans to a simple formula basis. I had taken the attitude that due to the large number of factors involved, set rules were difficult to formulate. This I still feel to be the case, although the tendency of well-designed factory buildings to adhere to fairly well-defined ratios of the window to the floor space may be taken to indicate the possibility of using such figures for new structures with proper precautions.

FIG. 1.



SOME FACTORS INVOLVED IN DAYLIGHT PLANNING.

I shall endeavor in the following paragraphs to show, first, some of the factors which the plans for interior natural lighting include, and then to point to the basis which may be taken in the formulation of simple rules for such work. First, consider the effect of adjacent structures. A window which might admit a generous supply of daylight is often rendered more or less useless by the presence of a taller building located only a short distance away. This is shown in the upper part of Fig. 1 by the line

passing from the upper part of the structure on the left, through the top of the window to the floor within. Any point on the bench surface to the right of the intersection of this line with the surface receives no direct light from the sky through the left window. Similarly, no point on the floor to the right of *a* in the diagram receives any light directly from the sky through the left window. This does not mean, of course, that those parts of the floor to the right of *a* are in darkness, but the light must come from reflections from the opposite building face or from reflections from those parts of the building interior which receive light directly from the sky, as far as the left window is concerned. The actual daylighting effect in such a building might be decidedly different from that in an exactly similar structure where such an obstruction (that is to say, the building on the extreme left) did not exist, and it is just such a factor that the constants of ratio of window to floor area cannot in themselves well include.

MULTIPLE STORY BUILDINGS.

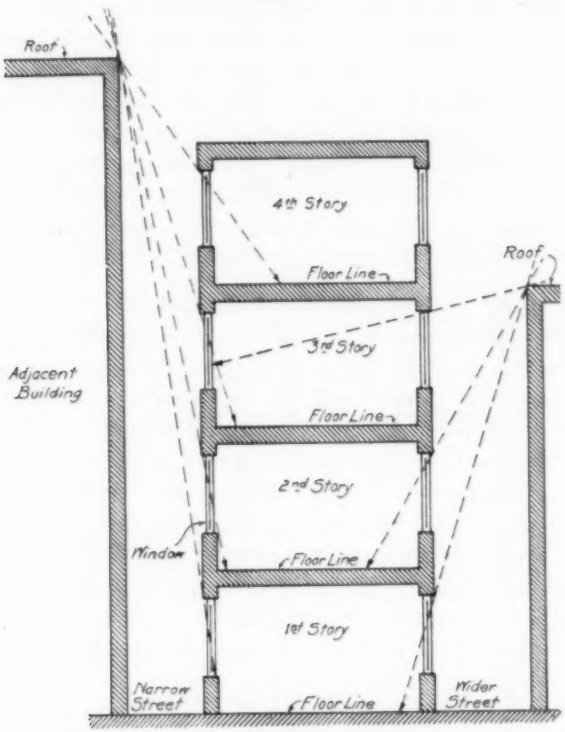
Similar obstruction effects are often very pronounced in the lower floors of multiple story buildings. Note in Fig. 2 the fact that the window to the right in the fourth floor admits light directly from the sky all the way across the room, whereas the effect of the taller structure to the left is to curtail to a considerable extent the effectiveness of the fourth floor window on the left. Left windows on the first floor are practically useless as far as any light directly from the sky is concerned. Effects of this kind are experienced daily in the offices of tall office buildings in congested parts of the city, where artificial light is required continuously throughout many days in spite of the normal window areas provided.

An inspection of Fig. 2 will show that if the ratio of window area to floor area is specified from tables of such constants without regard to differences in the effectiveness of the windows for the various floors, the actual illumination will vary considerably for different floors unless some special devices, such as suitable prisms, are used for the lower floors to re-direct the light over wider floor areas than is possible with plain window glass. Put in another way, a set rule for the ratio of window area to floor area, in a case like Fig. 2, might give adequate interior lighting for the upper floors but it might be very inadequate for the lower floors.

LIGHT TRANSMITTED THROUGH WINDOW GLASS.

Fig. 3 indicates the decrease in the per cent. of light transmitted through plain window glass in terms of the light incident upon the outer surface of the window for various angles of incidence, the definition of angle of incidence as here employed being expressed by the small auxiliary diagram at the top of the figure.[7]

FIG. 2.

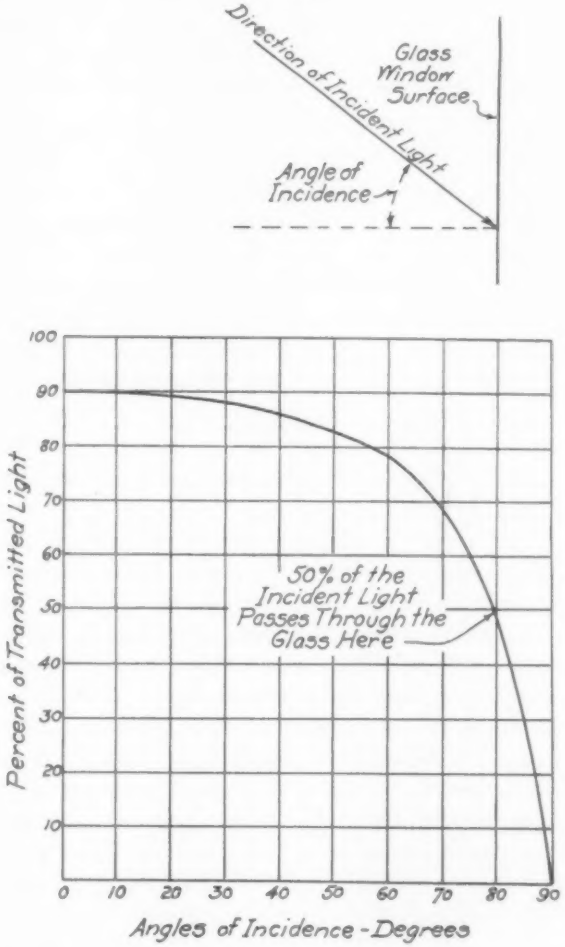


This diagram illustrates the importance of rather low angles of incidence for plain window glass if the per cent. of transmitted light is to be large. Where the angles of incidence are high, as with the lower story windows of tall buildings with other tall buildings opposite, the amount of transmitted light for plain glass is reduced, in general, according to this curve, and the necessity

[7] See "Principles and Design of Interior Illumination," by L. B. Marks. "Lectures on Illuminating Engineering," *Johns Hopkins Press*, Vol. ii, p. 663. See also *Metal Worker, Plumber and Steam Fitter*, Jan. 4 and 18, and Feb. 1, 1918.

of special types of glass for the re-direction of the light into the building becomes relatively greater. This curve starts with 10 per cent. at zero angle of incidence, meaning that plain window glass is assumed to absorb about 10 per cent. of the light normally

FIG. 3.



incident upon its surface. I am indebted to Dr. Peter A. Callan, of New York City, for a reference to the work of Sir William Crookes, about 1909, on glass. He mentions what is termed glass No. 187, made up of fused soda flux 83 per cent., and cerium

nitrate crystallized 17 per cent., for which the claim is made that 99 per cent. of the light incident to the surface is transmitted.[8]

TYPES OF FACTORY WINDOW GLASS.

The use of types of glass other than plain glass for factory windows has received considerable attention. The well-known tests of Prof. Chas. L. Norton, of the Massachusetts Institute of Technology, along this line, may be summarized as follows: (*a*) That the common rough plate or hammered glass has very little action as a diffusing medium, giving no perceptible change in the effective light within the building; (*b*) that the light in a room 30 or more feet deep may be increased from 3 to 15 times its present effect by using factory ribbed glass instead of plain glass in the upper sashes; (*c*) that of the ribbed glasses, the factory ribbed with 21 ribs to the inch is distinctly the best, and not, in all probability, because of the fineness, but because of the greater sharpness of the corrugations; (*d*) that ribbed wire glass is about 20 per cent. less effective than the ordinary factory ribbed glass; (*e*) that prism glass, like the factory ribbed, is more effective in increasing the light when the light is restricted, as in a narrow alley or light shaft, than when the window has an open exposure with a wide sky angle; and (*f*) that rooms with windows opening upon light shafts and narrow alleys with very limited sky, where the available light is now small, may have the light 20 feet back from the windows increased ten to twenty times by using prisms.[9]

The Aberthaw Construction Company has derived the following conclusions from information they have gathered, namely, that (1) the ribbed glass, prices being equal, is under all conditions better than the rough or hammered glass, giving more light under favorable conditions and as much light under all conditions; (2) the objection due to dirt and dust collection on the rough surfaces can be obviated; (3) prism glass is really worth while and will positively increase the amount of light under certain conditions; and (4) ribbed wire glass is about 20 per cent. less effective than ordinary factory ribbed glass.

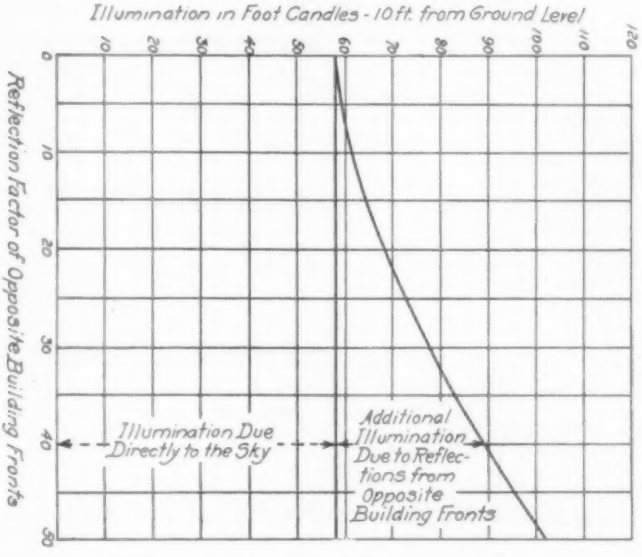
[8] Philosophical Transactions of the Royal Society, London, Series A, Vol. ccxiv, pp. 1, 25.

[9] From information submitted by the Aberthaw Construction Company, for the use of the Employment Management Division of the War Industries Board, 1918.

REFLECTIONS FROM OPPOSITE BUILDING FRONTS.

The effect of reflections from opposite building fronts has been investigated and the curve in Fig. 4 shows the results for various reflection constants of the adjacent or opposite building faces.[10] The curve here shown is based on three reflections from

FIG. 4.



the opposite building front, and indicates the importance to interior lighting in relatively narrow streets faced on each side by high buildings of having the fronts of the building light colored. Factors of the kind just discussed show that various factory buildings of the same general outlines and with equivalent ratios of window to floor area may have widely different daylight illumination effects throughout their interior working surfaces.

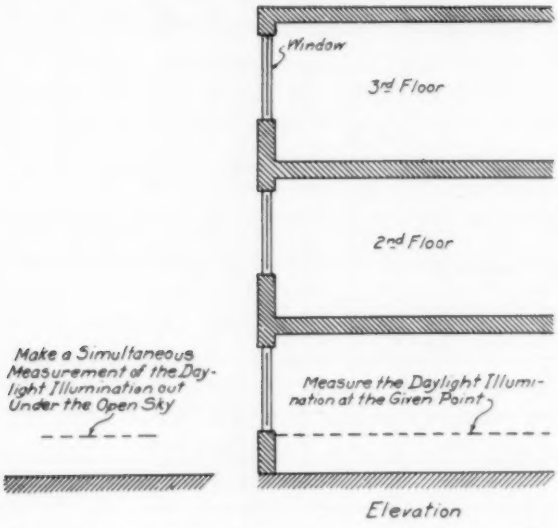
THE DAYLIGHT FACTOR.

It is of interest at this point to consider the natural illumination within a factory in comparison with that at a point outside the building under the open sky. These differences have been commented upon from time to time by various writers, but their significance to the interior lighting problem, particularly in older

[10] See reference quoted in footnote 7, p. 665. Based on original tests of C. O. Basquin.

structures, may readily be overlooked. The ratio of the illumination intensity at a point within a factory to the intensity at the same point, if it were exposed to the open sky, may be termed a measure of the daylight efficiency of a building for the given point, and it is sometimes called the "daylight factor" for the given point.[11] A simple suggested method for determining the

FIG. 5.


Window
3rd Floor
2nd Floor
Make a Simultaneous Measurement of the Daylight Illumination out Under the Open Sky
Measure the Daylight Illumination at the Given Point
Elevation

daylight factor for a given point within a building is shown in Fig. 5. Average values of the daylight factor in a report issued by the British Government range from 0.25 to 2.3 per cent. for given cases investigated, of course with values above and below these averages, and the lowest values referring to day lighting with side windows only.

The extreme variations of exterior natural illumination intensities are suggested by Fig. 6,[12] which shows the conditions for June, September and December in one geographical location. It is now possible to work out for any given daylight factor corresponding to one or more points within a factory, what the intensities of

[11] Suggested by A. P. Trotter and subsequently developed by P. F. Waldram. See the First Report of the Departmental Committee on Lighting in Factories and Workshops, London, 1915, p. 38.

[12] See footnote 11, p. 64, of the Report referred to. Some daylight measurements in this country may be found in Trans. I. E. S., Vol. xi, No. 3.

FIG. 6.

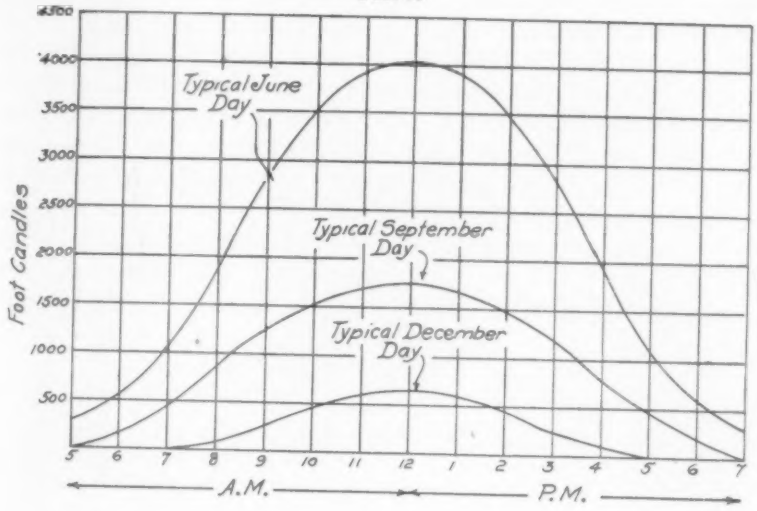
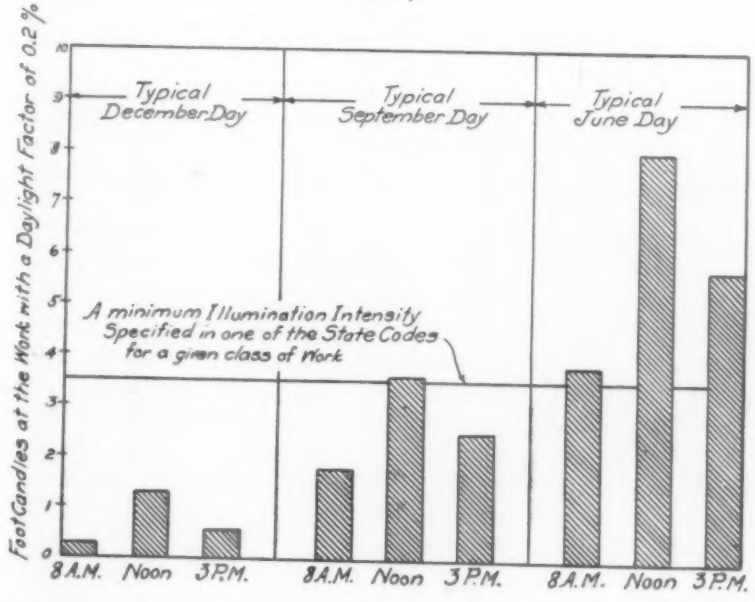

Typical June Day
Typical September Day
Typical December Day
Foot Candles
4500
4000
3500
3000
2500
2000
1500
1000
500
5 6 7 8 9 10 11 12 1 2 3 4 5 6 7
A.M.
P.M.

FIG. 7.

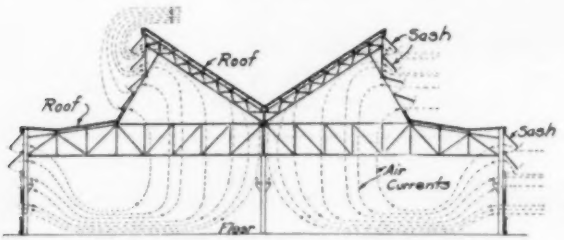

Foot Candles at the Work with a Daylight Factor of 0.2%
Typical December Day
Typical September Day
Typical June Day
A minimum Illumination Intensity Specified in one of the State Codes for a given class of Work
8 A.M. Noon 3 P.M. 8 A.M. Noon 3 P.M. 8 A.M. Noon 3 P.M.

natural lighting will probably be at different hours of the day and for different days of the year. This may be done in conjunction with a set of curves similar to those in Fig. 6 corresponding to the geographical location in question. Fig. 7 indicates the intensities for 8 A.M., at noon and at 3 P.M. for what may be called typical December, September and June days and shows that for the assumed daylight factor the intensities fall below 3.5 foot-candles all day on typical December days and for a part of the day on typical September days. Values worked out on this basis could readily be used to show roughly the number of hours per day for various months when the daylight should be supplemented by artificial light.

MODERN FACTORY BUILDING CONSTRUCTION.

The structural developments in factory building design have been quite marked in recent years. Fig. 8 indicates, for example,

FIG. 8.



the section of a patented Pond truss of the David Lupton's Sons Company, where the problem of ventilation has been combined with that of the natural illumination. The dotted lines in this figure show the ventilation air currents, while the under concrete surfaces of the V-shaped structure furnish reflecting backgrounds for re-directing the daylight, admitted through the upper windows, to the floor beneath, and thus tend to distribute the daylight uniformly on the working surfaces throughout the shop. Fig. 9 indicates one of these buildings in the process of construction, while Fig. 10 shows the interior of such a structure after completion. Some idea of the uniformity of the interior illumination may be gained from this view.

The expense of steel sash for factory windows is roughly equal to the equivalent wall area under certain assumptions as to the thickness of the walls and the types of construction in-

FIG. 9.

FIG. 10.

volved. As the area of window space increases for given floor space, however, the heating facilities for the maintenance of a given temperature during winter months also increases and tends to offset the advantages which might be claimed for indefinitely increasing the sash area. Thus it has been found in one given case that the use of side wall windows instead of continuous sash, with a decrease in glass surface and a corresponding increase in solid wall area, would result in a less costly heating plant, the

FIG. 11.

heating plant with continuous sash and the increased glass area for this particular case costing about 10 per cent. more than where side wall windows with a decreased glass area are employed. These figures apply, of course, to one given case only. (Reported by Mr. E. U. Smith.)

The regulation of windows and continuous sash for ventilation purposes is of course important, and in Fig. 11 the ability to open the long lines of so-called Lupton continuous sash is demonstrated, such motion being possible either by hand or by power operated devices.

The possibilities of highly adequate daylight facilities through

properly designed buildings are probably apparent from the foregoing notes. Specific rules would be desirable for window planning in factory buildings, but the above shows that the problem is complicated by factors of design. Simple rules will doubtless materialize, and in fact it would be possible here to append ratios of window area to floor area for a great variety of factory structures, but they may readily be obtained by anyone interested in the problem from the sash manufacturers and, moreover, it is well to remember that such figures, in themselves, may at times be misleading and should only be applied to a proposed new building if they include in their application such important considerations as typified by (*a*) adequate daylight in all parts of the building during normal daylight hours; that is to say, the suitable distribution of the light; (*b*) the avoidance of extremes in glare, and (*c*) proper limits, without prejudice, of course, to the adequacy of the natural illumination, governed by heat losses where window areas are made too large and where the heating costs increase correspondingly.

ENGINEERING DETAILS OF ARTIFICIAL LIGHTING.

The comparative simplicity of the design of artificial lighting systems in contrast to those for natural lighting has already been referred to as being due partly to the possibility of a more symmetrical arrangement of lamps, when mounted overhead, and when referred to the working surfaces which are distributed through the floor space, than where side windows are depended upon as the sole source of the natural light. This is made clear by a comparison of Figs. 12 and 13. In Fig. 12 it will be noted that there is a lack of symmetry in the distribution of the daylight on the floor area, the intensities being greater near the side wall windows and fairly deep shadows being cast on the floor near the centre of the room. Of course, it is apparent that if roof lighting is employed, the distribution of daylight can be made much more uniform than in Fig. 12, but roof lighting is limited to single story buildings or to the top floors of multiple story structures. Fig. 13 shows a factory space with the artificial lighting system in use at night. It will be noted in Fig. 13 that the distribution of light over the entire floor and working areas is unusually good, due to the symmetrical arrangement of the mercury vapor lamps over the ceiling area. This view also indicates in an exceptional manner the great advantage in the use of medium-sized lamps for

FIG. 12.

FIG. 13.

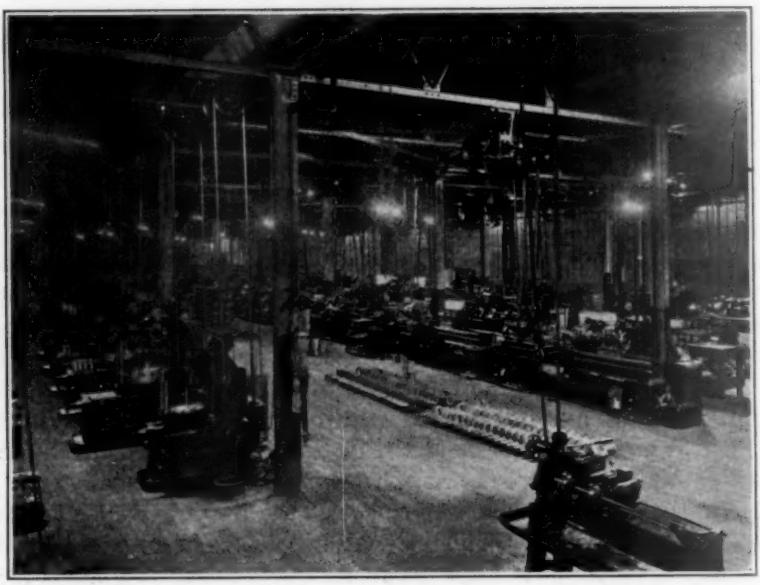


FIG. 14.

FIG. 15.

factory spaces with intermediate ceiling heights such as here shown.

TYPES OF LAMPS.

The principal types of electric lamps now used for factory lighting are the Mazda and the mercury vapor types. Arc lamps, although used to some extent in earlier practice, have given way in many cases for interior industrial purposes to the other types. A typical Mazda lamp installation is shown in Fig. 14, while Fig. 15 shows a section of the Gould and Eberhardt works at Irvington, N. J., equipped with mercury vapor lamps. In addition to the lamps down the central part of this aisle, it will be noted that the same type of lamp is employed under crane runways on either side of the aisle for the illumination of benches and nearby floor space. Either system, that is to say, with Mazda or with mercury vapor lamps, can be planned so as to give excellent results, and quite a number of industries make use of both systems, employing the mercury vapor lamps in those parts of the shop where the particular quality of light from such sources is considered as meeting the special needs of the work, and the Mazda lamps in other departments.

REFLECTORS FOR MAZDA LAMPS.

With the Mazda lamps the need of reflectors is particularly great on account of the character of the distribution of the light from the bare lamp, and also because of the great brilliancy of the lamp filament. In fact, the design of any industrial lighting system should be based upon a careful study of the reflectors to be used with such lamps, if the system is to be effective and highly efficient in the utilization of the available light. Fortunately, a good deal of attention has been given to reflector design and the types now on the market are sufficient to meet ordinary needs provided they are selected intelligently. Standards, which take into account the factors which the reflector should accomplish and the proper points in the design of the reflector to meet these factors, have been developed, and it is planned to market such a standard line of lamp auxiliaries under the trade designation of the R L M standard.

An interesting development in recent reflector design has been worked out in the so-called " Reflecto-Cap " type, in which a small cap is placed beneath the lower part of the lamp bulb, thus protecting the eyes of employees from the brilliancy of the filament itself.

The inner surface of this close-fitting cap is finished so as to be a good reflector and thus re-directs a fair proportion of the light that would ordinarily go downward to the under side of a large metal reflector placed above the lamp. This scheme approximates an increase in the area of the light source and produces a less harsh effect than that of a system in which the bare filament of the lamp is visible. A system of lighting making use of this Reflecto-Cap unit is shown in Fig. 16, and the excellent quality

FIG. 16.

and distribution of the light is evidenced, to some extent, by the freedom of shadows on the floor space, in spite of the numerous machines in this shop.

THE OVERHEAD VERSUS THE LOCALIZED SYSTEMS OF LIGHTING.

In Fig. 17 a good example is shown of what may be termed the overhead or the general system of factory illumination, these terms being used to distinguish it from the older, although frequently used system of local lamps placed close to each machine or directly above and close to each bench surface. In older practice, it was often found that some general illumination from overhead lamps was desirable in addition to that of lamps close to individual

machines. The function of the general illumination in such cases was to furnish some light to the spaces between machines and in the aisles, the latter spaces ordinarily being provided with a less intensity than the points of work directly under the local lamps. The possibilities of using Mazda and mercury vapor lamps overhead and in such density of numbers as to furnish highly adequate illumination over the entire floor area, has led to quite a general adoption of this method of lighting by many progressive plants.

FIG. 17.

The illumination of the entire floor space of a factory section to an intensity adequate for accurate workmanship might seem at first to be an uneconomical procedure inasmuch as a part only of the floor space is usually so used at any one time. However, the following advantages commend it as worth while: (*a*) With every part of the floor space equally well lighted, work may be conducted at any point of the floor without regard to the location of the lamps. This makes it possible to arrange the work, the benches, assembly and other operations, in such a way as to facilitate the sequence of operations and so as to accommodate the best scheme of routing materials, without any regard to the

lamps. If it becomes desirable from the standpoint of manufacture to move a bench or to rearrange the location of some of the machinery, local lighting nearly always requires some readjustments of the lamps and the wiring, which is not only expensive but a decided inconvenience. (*b*) The prevalence of shop accidents in aisles and spaces adjacent to machines rather than at the machines themselves, indicates the importance of adequate light not only at the machinery but also in the adjoining spaces. The general overhead system obviously takes care of this point. (*c*) Moreover, the idea that machine tools should have a local lamp or lamps close to the working position of the operator is often erroneous. Where the general lighting is made adequate in intensity and where the side component of the illumination is sufficient from overhead lamps to illuminate successfully the sides of the work in such machines, the problem may readily be solved, in many cases by the overhead scheme, without resorting to individual or local lamps.

INTENSITIES OF ARTIFICIAL LIGHTING.

Three principal points stand out in the design of any factory lighting system, namely, *the quantity of the illumination* to use for given classes of work, *the proper distribution* of the light, and *the avoidance of glare*. These points, without regard to other items which must often also be taken into account, are fundamental to the success of the average system. Although the quantity of light is often popularly looked upon as the item of greatest importance, at the present time the avoidance of glare may be taken as probably more vital to the interests of eyesight than either of the other items just mentioned. This statement is based upon the unusual neglect of factory owners to employ shielding devices, such as reflectors or shades, with the brilliant Mazda lamps which are now so commonly used. It may be noted, however, that while the use of reflectors is practically fundamental to the avoidance of glare with Mazda lamps, the use of reflectors also bears very closely upon the other two factors of quantity and of distribution of light.

It is well to note that a comparison between natural and artificial lighting indicates that the ordinary intensities of natural light are far in excess of those which can economically be looked for, or which are even necessary with artificial lighting. The eye possesses a marked degree of flexibility in the illumination

intensities with which vision is possible and comfortable. A simple test of this is to read a newspaper in the elevated or subway surface cars just before entering the subway from daylight conditions and to note that little effort is required to continue reading comfortably under the electric car lamps, although the intensity of the artificial light may be very small in comparison with the intensity of the previous daylight. Another impression may be gained of these large differences by noting that interior intensities of 50 or more foot-candles are common near windows by day, whereas at night, reading may be done comfortably with artificial lighting intensities of, say, two or three foot-candles; that is to say, only 5 per cent. of the foregoing daylight value. This means that due to the peculiar adaptability of the eye to lower intensities of artificial illumination at night, it is not necessary to provide nearly as high intensities with an artificial lighting system as would at first be supposed based merely upon what might be termed daylight standards. When artificial light is required to supplement inadequate daylight, however, then it becomes more important to consider higher intensities of the artificial illumination because of its direct competition under such circumstances with daylight values.

INTENSITY STANDARDS.

The whole question of intensity values to employ for any given demands upon vision, such as those imposed by various classes of work or different degrees of refinement in the discrimination of detail in the objects looked at, is one which does not yet seem to have been conclusively demonstrated. Illuminating engineers, and in fact practically anyone who is called upon to decide how much light to furnish for given working operations, usually depend upon their judgment, which is often based upon conditions which have seemed satisfactory in other similar locations. This scheme is safe as far as it goes, but it is very difficult to tell when a given system is satisfactory from every standpoint of vision. I have seen a lighting system installed which was far superior to the older system that it superseded, but which, at the same time, was inferior to a still better system that was later proposed. Here the employees thought the second improved system was very satisfactory because of its comparison with a very much inferior system. The judgment of the employees here, if taken on a basis of what was considered satisfactory, might have

been materially different from what it would have been had they been asked for an opinion under a still more nearly ideal arrangement of lamps.

I feel strongly that the specification of the proper quantity of illumination to use for varying visual demands is a matter which is far from solved, and that probably the only way in which it could ever be solved positively would be to take ophthalmological observations upon given observers under a given class of work for different degrees of illumination intensity and over sufficiently long periods to take into account the effects of the illumination upon permanent depression of the eyesight. Temporary judgments based on casual observations do not take into account this factor of long continued use of the light and hence lack at least one element involved. The excellent work of Ferree and Rand at Bryn Mawr College has given to the lighting art a good deal of useful information along this general direction.

SAFETY STANDARDS OF INTENSITY.

There is another side of intensity specifications, however, which can be approached with somewhat more confidence, and this is the matter of providing enough light to safeguard employees against accidents and to specify minimum values below which manufacture cannot well be conducted without a likelihood of time losses and inaccuracies in workmanship. The state codes now in force in several of the states, which have been based on the code prepared by the Committee on Lighting Legislation of the Illuminating Engineering Society,[13] have included specifications on this *minimum* basis, and then usually add for each class of work a higher value, which is headed as a *desirable* intensity.

In the preparation of tables of suitable intensities of illumination for all classes of work, and for the various ramifications of manufacture, two difficulties present themselves, the one being a lack of information on just what the illumination requirements are for these almost infinite operations, with their varying shades of form, color and detail, and the second being the cumbersome extent of such a list which would endeavor to cover all cases. In the original code of the Illuminating Engineering Society, all industrial processes were summarized under the four heads: (*a*) Storage, passageways, stairways, and the like; (*b*) rough manu-

[13] Mr. L. B. Marks, of New York City, Chairman.

facturing and other operations; (*c*) fine manufacturing and other operations; and (*d*) special cases of fine work. Later, these lists of classification groups have been elaborated somewhat, although the Illuminating Engineering Society's code has been based on this general scheme of classification through its revisions, with the addition of several groups. There is a tendency in one and another of the state codes to amplify the lists of operations and to specify intensities for a larger number of detailed cases.

DISTRIBUTION AND GLARE.

The question of how the light should be distributed over a factory floor area is one which must be determined by the density of the work and how near an approach may be desired towards a perfectly uniform condition throughout the entire floor space. Reflectors perform an important function in the correct distribution of light from lamps, which, by themselves, might not result in nearly so satisfactory a lighting system.

The avoidance of glare is of the utmost importance, and has already been touched upon. In its simplest form, the avoidance of glare is approached by the workman when he surrounds his otherwise bare local lamp with a piece of paper, or hangs up a piece of cardboard in front of the lamp so as to prevent the strong light of the lamp from shining directly into his eyes. From several standpoints, the proper attention to this feature in the lighting system is one of the most important items of all, and one authority has gone so far as to say, in effect, that if no other improvements were made in existing systems of factory lighting than the equipment of each lamp with a suitable reflector so as to cut off from the eyes all direct rays from the brilliant filaments, that considerable improvement would probably be made in the reduction of industrial accidents. Obviously, the reduction of eye strain and the improved workmanship, which such a course would promote, would also be decided advantages.

MAINTENANCE OF THE SYSTEM.

The effects of light colored surfaces for walls, ceilings and columns have long been recognized as quite a factor in the effectiveness of lighting conditions, both natural and artificial. White or light-tinted paints and frequent cleaning are two factors to consider. The reader is referred to the lecture on the "Principles of Interior Illumination," by Cravath, Harrison and Pierce, in

the volume of lectures given under the joint auspices of the University of Pennsylvania, and of the Illuminating Engineering Society,[14] in which valuable data are given regarding the variations in the utilization efficiency of various systems of light in its dependence upon wall and ceiling conditions. One of the paint manufacturers has recently issued a readable bulletin under the heading of " Barrelled Sunlight " which very appropriately emphasizes this phase of factory lighting.

It will, perhaps, be seen that no lighting system can maintain its original effectiveness unless the lamps and reflectors are cleaned at proper intervals and unless burned-out lamps are renewed promptly. This is of such fundamental importance to the continued success of any lighting system that some space might well be devoted to the importance of maintenance and to methods for conducting such work, in preliminary reports submitted to building owners on proposed lighting systems. Lamp and reflector cleaning are items which are so readily overlooked that the average user of light requires education along this line if his appreciation of the needs of the case is to result in systematic adherence to the work. One of the best plans I have ever seen of this kind is that adopted some years ago at the East Pittsburgh Works of the Westinghouse Electric and Manufacturing Company, where the maintenance of the very large lighting system is conducted by a special Division of the electrical department. Here, the original plans of the work included systematic inspection of all lamps each day for the purpose of locating every burned-out lamp and for noting equipment in need of cleaning. On the basis of these daily inspection reports, the maintenance work may be conducted effectively and a record can be kept of the costs for such work which forms an interesting basis for a comparison between the costs of the maintenance work and the gains produced by the higher standard of illumination thus maintained.

STATE REGULATIONS.

The original code of factory lighting issued by the Illuminating Engineering Society several years ago has since been used as the basis for state regulations in Pennsylvania, New Jersey, Ohio, New York and Wisconsin. Furthermore, the Committee on Labor of the Advisory Council for National Defense issued

[14] Published by the McGraw-Hill Book Company, New York, 1917.

through its Divisional Committee on Lighting [15] a code based quite largely on that of the Illuminating Engineering Society. Many of these codes contain modifications in the general arrangements or in the addition of explanatory matter not found in the original Illuminating Engineering Society's code, but the three fundamental items of *intensity, distribution* and the *absence of glare* form, for the most part, an important place in all of these regulations.

The issuance of the state codes has, of course, been based on the safeguarding of employees and they have sought to reduce accidents and to prevent premature eye trouble by the stipulation of safe methods and amounts of illumination for various factory operations. In one of the recent state codes, the factor of conserving time by permitting employees to do more and better work, without additional effort, in a given time, through the medium of better light, was emphasized as a factor which might influence the wealth of the state.

Realizing that the state factory inspectors, upon whom the application of these codes fall, would probably find difficulty in grasping the full meaning of such rules because of the newness of some of the ideas they contain, the University of Pennsylvania invited state factory inspectors of Pennsylvania and of New Jersey to a series of lectures on factory lighting at the University in the spring of 1918, and these proved to be very acceptable to the state labor departments concerned. I am informed that the Department of Labor of New Jersey is planning to continue this general scheme of education among its factory inspectors by lectures within the state from time to time.

Where intensity of illumination is specified, as in these relatively new codes, the need of a simple device for the measurement of illumination by relatively inexperienced people has been keenly felt. The appearance of the small and very convenient "Foot-Candle-Meter" (see Fig. 18), as a result of the work of Dr. C. H. Sharp, of New York City, has, in a way, met this need, and it is, I believe, employed to a limited extent by the Departments of Labor in Pennsylvania and New Jersey.

PROBLEMS ADDED BY THE WAR.

While the stress of war conditions is now largely over, it is

[15] Of which Mr. L. B. Marks, of New York, is chairman.

interesting to review, in conclusion, a few of the things which affected lighting practice due to those unusual conditions. One of these, of course, was that of protective lighting about industrial plants as a safeguard against damage to the plant, and this type of illumination received a good deal of attention and was employed very effectively in many cases. Another was that of lighting curtailment, as one of the points taken up by the Federal

FIG. 18.

Fuel Administration, and here, as previously stated, it was found that of all the divisions of lighting, the industries were the one field in which increases rather than curtailment in lighting were desirable, thus emphasizing the importance with which the problem of industrial lighting was viewed during the war as a strictly war problem.

The emphasis which was placed upon good light by the Employment Management Division of the War Industries Board in its efforts to educate employment managers under the intensified training scheme then in vogue, and the hope which was entertained that a high standard of working environment—that is to say, good light, fresh air, adequate heat, cleanliness and neatness about the

plant, and the like—would all go to prevent the excessive turnover of labor during the progress of the war in the war industries, all go to demonstrate the important place which industrial lighting holds in the industrial field.

The foregoing notes, while not in any sense a scientific analysis of factory lighting from the quantitative side, have given a general outline of the factors involved in the problem. With these in mind and thoroughly accepted and appreciated, the actual detailed planning for industrial lighting systems possesses the possibility of an interesting field for study and certainly contains an element of compensation for those who devote time to such work, through the beneficial effects which good lighting may accomplish for those whose vision and whose workmanship depend to such an extent upon facilities of this general nature

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Salt Deposits of the United States. W. C. PHALEN. (*U. S. Geological Survey Bulletin No. 669.*)—The Delaware Indians made salt from brine springs in New York State and sold it to settlers as early as 1670, making probably the first commercial production of salt in this country. The manufacture of salt by white people in the United States was begun near Syracuse, N. Y., about 1788. Salt is the most commonly used mineral in the world, and no useful mineral except coal, perhaps, occurs in greater abundance or is more widely distributed in the United States.

The Federal and State Surveys and private establishments have published a great deal about the occurrence of salt in parts of the United States, but not until now has so much information on the salt deposits of the whole country been assembled in a single volume. The distribution and character of the salt deposits are described by States and a brief history of the industry is given, together with a record of the output since 1797. The report also contains a discussion of the origin and formation of saline deposits and many chemical analyses of brines and bitterns.

Wood Waste. (*Weekly News Letter, U. S. Department of Agriculture*, vol. vi, No. 47, p. 5, June 25, 1919.)—A particularly interesting field of possibilities for greater utilization of wood and wood waste as a result of the Forest Products Laboratory's war work is the use of built-up and fabricated construction. This is merely utilizing small pieces of wood and a glue which will make a joint as strong or stronger than wood, and building them up in the forms desired. It was found, for example, that a laminated wing beam for airplanes could be constructed as strong as a solid beam, and this at once made possible a great increase in the utilization of spruce material which otherwise had to be eliminated from aircraft construction.

HIGH FREQUENCY CURRENTS ON WIRES.*

BY

J. O. MAUBORGNE, Lieut. Col., Signal Corps, U. S. A.

ATTENTION was first directed, in 1911, to the practical utility of employing high frequency electric waves for transmission of energy along wires by Major (now Major-General) George O. Squier. The discussion following the publication of his results indicated that, in the minds of many, the opinion prevailed, that because of the excessive attenuation obtaining at the "ultra audio" frequencies, the system would be inoperative over great distances. This was thought to be particularly the case if frequencies greater than 100,000 cycles per second were employed.

Recently this subject has assumed an important aspect from a military standpoint and it was decided to conduct further experiments with the object of examining the possibility of adapting certain existing types of radiotelephone and telegraph apparatus to multiplex operation. The results of the few preliminary tests which have been made recently by First Lieut. R. D. Duncan, Jr., and Radio Engineer Samuel Isler of the Engineering and Research Division, Signal Corps, Washington, D. C., are of interest because they have shown that not only is it possible to transmit energy, at least in sufficient amounts to actuate standard "radio" receiving apparatus, over comparatively long lengths of wire circuits, but that frequencies considerably in excess of the value hitherto named as the upper limit could be employed.

The apparatus used in these tests is known as the SCR-67, which is the ground set of the standard ground-airplane radiotelephone equipment. It comprises two, three-electrode vacuum tubes, of the transmitting type (Type VT-2. One oscillator and one modulator) and connected circuit, a receiving tube (Type VT-1) and circuit, and a two-stage audio frequency amplifier. The method of modulation, that devised by Heising, is based on the fact that, to a very close approximation, the amplitude of the high frequency current is directly proportional to that of the

* Communicated by Maj.-Gen. George Owen Squier. An abstract of this paper was presented at the Washington Meeting of the American Physical Society, April 25, 1919.

emf applied between the plate and the common filament terminal of the oscillating tube; any variation of the *emf*, for example, at an audio frequency, will modulate or mould the continuous flow or high frequency energy in a corresponding manner, which when received by a tuned receiving circuit and rectified, manifests itself as an audible sound in a telephone receiver. The means by which the modulation is accomplished is by a second tube, whose plate filament path resistance is varied in accordance with the speech frequencies applied to its input terminals. By properly interconnecting the plate or output circuits of the oscillating and modulating tubes, and by further converting the high voltage plate power supply to the two tubes from a constant potential to a constant current system the variation in amplitude of the high frequency current may be made to follow out faithfully the variations impressed by the modulating source. This system is advantageous since the completeness and purity of modulation is practically independent of the frequency of the oscillating system.

The line may be connected to the source of oscillations in a number of ways, of which probably the most convenient is by inductive coupling.

To provide a practical means for carrying out of the tests, a wire, running from Washington, D. C., to New York City, was placed at the disposal of the Signal Corps by the Postal Telegraph Company. This line was duplexed and was in continuous operation by the Postal Company. In the first series of tests one multiplex station was established at the Signal Corps Radio Laboratory, Bureau of Standards, Washington, D. C., and a second at Dixon's Park, Curtis' Bay, Md., approximately three miles from the Postal office in Baltimore, the total wire distance between the two approximating 60 miles. The multiplex apparatus was connected to the line at these two points.

Satisfactory two-way communication was obtained; speech was received at both stations, loud and with exceptional clearness, the distortion common and inherent to long distance wire telephony being completely absent. The tuning at the receiving stations was quite definite, comparable in every respect to that when receiving signals of a " sharply " tuned radio station. This last fact permits of the operation of a number of multiplex units, each tuned to a different frequency and without the use of filter circuits on the same wire line. The carrier frequency employed in these tests was 600,000 cycles per second (wave length 500

metres); the effective line current, measured at each of the transmitting stations, averaged 60 mil-amperes. Throughout the tests the operation of the multiplex apparatus in no way interfered with that of the wire telegraph apparatus nor was interference experienced from the latter.

The satisfactory range of an SCR-67, when operating as a ground "radio-telephone" set, in communication with a corresponding SCR-67, is, under ordinary conditions, 10 miles. Thus by confining and directing the flow of energy to a definite direction, the range is materially increased.

The advantages of multiplex telephony and telegraphy are many. From a military standpoint alone, it is obvious that in time of war, any means of increasing the traffic handling capacity of already overburdened telephone and telegraph lines will be of inestimable value. There is a further advantage from an economical standpoint, in that certain of the existing types of Signal Corps radio-telephone and telegraph apparatus, large quantities of which were purchased during the war and which are now idle, with only slight changes in construction, may be adapted to either radio or multiplex operation. The increased range obtained makes possible the connection of outlying military posts and establishments with low power units where ordinarily comparatively high power and consequently heavier apparatus would be required if strictly radio communication were solely relied upon.

OFFICE OF THE CHIEF ENGINEER,
ENGINEERING AND RESEARCH DIVISION, SIGNAL CORPS.
WASHINGTON, D. C., April 5, 1919.

Tunneling Under the East River. (*Scientific American*, vol. cxx, No. 26, p. 681, June 28, 1919.)—A very interesting bit of tunneling was recently done on the 14th Street tube under the East River, New York. The heading was being run in rock and at one point test holes showed a thickness of only eight inches of sound dry rock above the line along which the top of the tunnel was to run. As the tunnel was being driven without the use of compressed air it was decided to drop the upper heading four feet until this thin cover of rock was passed. The cast-iron lining was set in place at each side of this section and then the rock was removed very carefully by using a great many holes each loaded with about one-eighth of a stick of dynamite. As each bit of rock was removed to the arch the tunnel lining was set in place. By this means the dangerous section was tunneled without breaking through the thin shell.

Simple Gage for Measuring Compressions. ANON. (*Scientific American,* vol. cxx, No. 18, p. 453, May 3, 1919.)—One of the most common causes of lost power in an automobile is that the force of the explosion pressure depends upon compression pressure before the gas is ignited. If the compression is 80 pounds the explosive force acting against the piston top and imparting power to it will be about 400 pounds per square inch. If worn piston rings or leaky valves allow gas to escape when the piston is rising on its compression stroke, the resulting decrease to 50 or 60 pounds means a reduction of explosive pressure to about 300 pounds per square inch. Besides this diminution in pressure, there is a loss due to further leakage through the faulty retaining members.

A simple compression pressure indicating gage may be made by taking an old spark plug body, from which the porcelain has been removed and fit in a valve from a discarded inner tube by pouring melted babbit metal or solder in to fill the space between the spark plug shell and the valve. When the metal has set, the valve is found to be firmly imbedded in the soft metal. The spark plug is removed from the cylinder to be tested and the combination plug body and valve stem put in its place. As the engine is turned over briskly by either the hand crank or self-starter by an assistant, or the engine run slowly on the other cylinders, a tire pressure recording gage held against the valve will record the compression pressure just as it does air pressure inside a tire. If the pressure is low on all cylinders it is a good indication that the entire engine needs attention. It can be determined whether the compression is adequate by comparison with the same tests on a new car of the same model.

Failure of Concrete Stacks. ANON. (*Power Plant Engineering,* vol. xxiii, No. 12, p. 543, June 15, 1919.)—From the day concrete made its advent in building construction, its merits were fully recognized. It must be admitted that for a large number of structures there is actually no better material than concrete. It became evident very soon, however, that it is an entirely unsuitable material for any purposes where it is subject to attack of heat, products of combustion, or undiluted acids. One of the best structures in which such conditions prevail is the chimney.

For the moment, we do not want to discuss those where the structure collapsed during the construction or soon after. We refer for the present only to those which decayed rapidly soon after being put in use. The thin walls of the stack permitted rapid radiation of heat. Condensation took place on the inner side of the stack, and the condensate worked its way into the fissures, rapidly destroying the texture of the material, and attacking the reinforcing steel. The stacks started to lean, to burst open, or collapsed entirely. Recently this inherent defect has been in part overcome by using a lining of burned clay, extending the full length of the stack.

RADIO TRANSMISSION FORMULAS FOR ANTENNA AND COIL AERIALS.*

BY

J. H. DELLINGER,

Bureau of Standards.

THE aerial of a radio transmitting or receiving set is either a condenser or an inductance coil of large dimensions. It effects the transfer of power between the radio circuits and the ether. The coil aerial has the inherent advantage of serving as a direction finder and interference preventer, but is less effective quantitatively as a transmitting or receiving device than the condenser aerial commonly called the antenna. The practical question, how far can communication be maintained by a coil in comparison with an antenna, is answered by the following formulas, derived from electromagnetic theory. A flat-top antenna is considered, and a rectangular coil. Let h = height of antenna or coil, l = horizontal length, and N = number of turns of wire of coil aerial, I = current, λ = wave length, d = distance apart of transmitting and receiving aerials, R = resistance of receiving aerial circuit. The subscripts s and r refer to sending and receiving, respectively. All lengths are in meters.

Antenna to antenna:

$$I_r = \frac{188.\ h_s h_r I_s}{R\lambda d}$$

Antenna to coil:

$$I_r = \frac{1184.\ h_s h_r l_r N_r I_s}{R\lambda^2 d}$$

Coil to antenna:

$$I_r = \frac{1184.\ h_s l_s h_r N_s I_s}{R\lambda^2 d}$$

Coil to coil:

$$I_r = \frac{7450.\ h_s l_s h_r l_r N_s N_r I_s}{R\lambda^3 d}$$

These formulas were derived by the author two years ago and have been found useful in the Signal Corps and Navy work since

* Communicated by the Author. Complete paper to appear as a Scientific Paper of the Bureau of Standards.

that time. Either the equations as here given or the component equations giving the field produced by a given antenna or coil aerial and the received current produced by a given field, lead to the solution of questions of design which it would be difficult to settle by experiment. Such quantitative experiments as have been made have verified the formulas to 25 per cent. or better, some observed values of received current being higher and some lower than the theoretical values.

The actual current received when a coil aerial is used is frequently greater than the formulas indicate, because such an aerial acts both as a coil and as an antenna by virtue of its capacity to ground. This double action of the coil structure is likewise indicated by values obtained for radiation resistance and by the observed directional properties.

The use of the coil aerial is particularly advantageous, as may be seen from the formulas, for short waves. In most cases, the usefulness of the coil increases as its dimensions are made to approach the order of magnitude of the wave length. An advantage of the coil not apparent from the formulas is that its resistance can usually be made lower than that of the corresponding antenna.

BUREAU OF STANDARDS,
April 25, 1919.

Waterproof Glues in Automobile Manufacture. ANON. (*Forest Products Laboratory, Madison, Wisconsin, Technical Notes* No. F-14.)—Some of the new waterproof glues developed primarily for aircraft purposes during the war offer the possibility of overcoming a difficulty that has proved very annoying, both to the automobile owner and to the manufacturer, wherever linoleum is used on the running boards or as a covering for the floor of the car. Ordinary glues which are soluble in water are not very effective in cementing linoleum, and most automobile owners have soon discovered that the glue disintegrates and the linoleum comes loose after the car has been washed a few times.

Casein glues are admirably adapted to this purpose, and if the quality is right and they are properly applied the linoleum should give no trouble during the life of the car. Casein glues are exceedingly resistant to the action of water and retain a very high percentage of their original strength, even after long immersion under water. They are comparatively inexpensive, and the materials from which they are made are readily available in the market. They are applied cold and will set without the application of heat.

PRESENTATION OF THE FRANKLIN MEDAL.
MAY 21, 1919.

AT the Stated Meeting of the Committee on Science and the Arts, held March 5, 1919, the following resolutions were adopted:

"*Resolved*, That the Franklin Medal be awarded to Sir James Dewar, of London, England, in recognition of his numerous and most important contributions to our knowledge of physical and chemical phenomena, and his great skill and inventive genius in attacking and solving chemical and physical problems of the first magnitude."

"*Resolved*, That the Franklin Medal be awarded to Major General George Owen Squier, in recognition of his valuable contributions to physical science, his important and varied inventions in multiplex telephony and telegraphy and in ocean cabling and directing the Air and Signal Services of the United States Army in the World War."

CORRESPONDENCE WITH MEDALISTS.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY

APRIL 8, 1919.

Major General George Owen Squier,
Chief Signal Officer, U. S. Army,
War Department,
Washington, D. C.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of those workers in physical science or technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications. The award is minuted as follows:

> "That The Franklin Medal be awarded to Major General George Owen Squier, in recognition of his valuable contributions to physical science, his important and varied inventions in multiplex telephony and telegraphy and in ocean cabling, and his eminent success in organizing and directing the Air and Signal Services of the United States Army in the World War."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our Management, to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 21st, to receive this medal and certificate from our President.

A second medal has been awarded to Sir James Dewar, of the Royal Institution, London, and the Earl of Reading has been asked to come to the Institute at the same time to receive it for Sir James.

MAJOR-GENERAL GEORGE OWEN SQUIER, PH. D.
Chief Signal Officer, U. S. Army.
FRANKLIN MEDALIST, 1919.

You and Lord Reading will be asked to be guests of honour at a dinner to be given on the same evening, but in this connection our President, Dr. Walton Clark, will communicate further with you.

I am,

Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO:S

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

OFFICE OF THE SECRETARY

APRIL 9, 1919.

Sir James Dewar, D.Sc., LL.D., F.R.S.,
The Royal Institution,
Albemarle Street,
London, W1, England.

SIR:

I have the honour to inform you that The Franklin Institute has awarded you The Franklin Medal, founded for the recognition of "those workers in physical science or technology, without regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications." The award is minuted as follows:

> "That The Franklin Medal be awarded to Sir James Dewar, of London, England, in recognition of his numerous and most important contributions to our knowledge of physical and chemical phenomena, and his great skill and inventive genius in attacking and solving chemical and physical problems of the first magnitude."

The medal and accompanying certificate are being prepared, and the Earl of Reading, your Government's Ambassador Extraordinary and Plenipotentiary at Washington, has been requested to come to the Institute on the afternoon of Wednesday, May 21st, to receive this medal and certificate, on behalf of his Government, for you.

I am,

Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO:S

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
Philadelphia

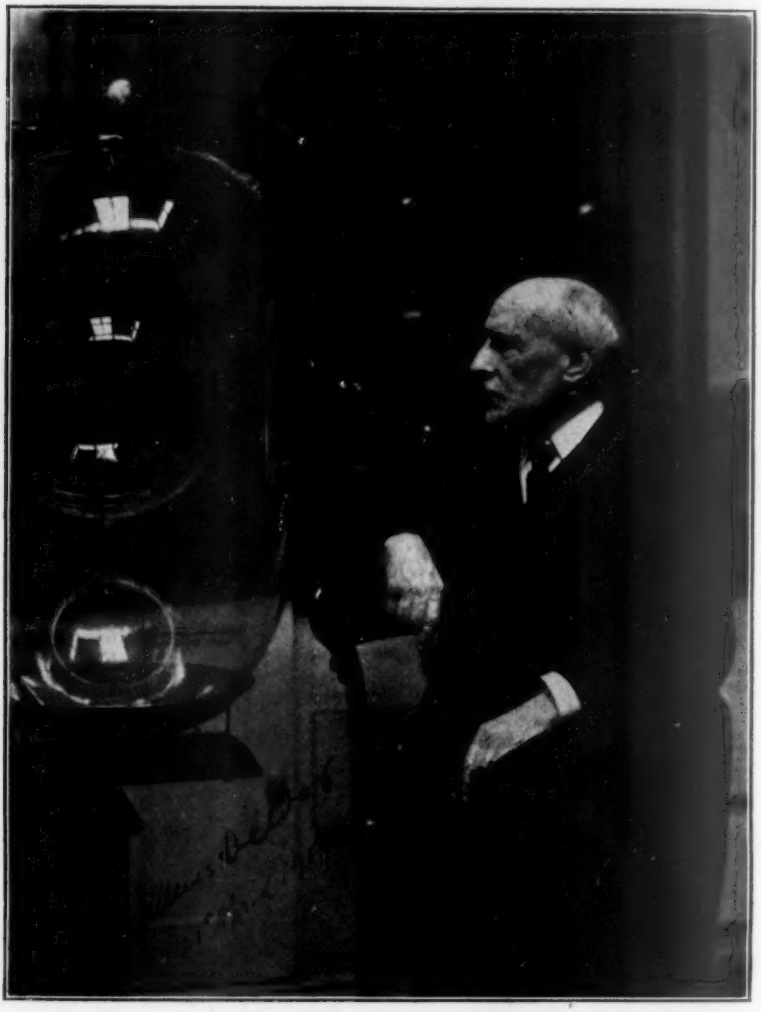
OFFICE OF THE SECRETARY

APRIL 9, 1919.

The Earl of Reading, Ambassador Extraordinary,
and Plenipotentiary of His Britannic Majesty,
British Embassy,
Washington, D. C.

YOUR EXCELLENCY:

I have the honour to inform you that The Franklin Institute has awarded to Sir James Dewar, of London, England, The Franklin Medal, founded for the "recognition of those workers in physical science or technology, without



SIR JAMES DEWAR, D. Sc., LL. D., F. R. S.
Jacksonian Professor of Experimental Philosophy, University of Cambridge;
Fullerian Professor of Chemistry, Royal Institution, London.
FRANKLIN MEDALIST, 1919.

regard to country, whose efforts in the opinion of the Institute have done most to advance a knowledge of physical science or its applications." The award is minuted as follows:

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The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 21st, to receive this medal and certificate from our President, on behalf of your Government, for Sir James.

A second medal has been awarded to Major General George Owen Squier, Chief Signal Officer, United States Army, in recognition of his scientific and technical achievements, especially with relation to communications.

You and Major General Squier will be asked to be guests of honour at a dinner to be given on the same evening, but in this connection our President, Dr. Walton Clark, will communicate further with you.

I am,
Your Excellency's very humble servant,
(Signed) R B. OWENS,
Secretary.

RBO:S

WAR DEPARTMENT
OFFICE OF THE CHIEF SIGNAL OFFICER
Washington

APRIL 11, 1919.

Major R. B. Owens,
Secretary, The Franklin Institute,
Philadelphia, Pa.

SIR:

I have the honor to acknowledge the receipt of your communication of April 8, 1919, advising me that The Franklin Institute has made an award to me of The Franklin Medal.

Allow me to express my deep appreciation of the very great honor conferred upon me by the Institute through this award.

It gives me great pleasure to accept, subject to the exigencies of the public service, the very cordial invitation which you have extended to me, to come to the Institute on the afternoon of Wednesday, May 21, 1919, to receive this medal and certificate from your President.

I remain,
Faithfully yours,
(Signed) GEORGE O. SQUIER,
Major General,
Chief Signal Officer of the Army.

BRITISH EMBASSY
Washington

APRIL 12, 1919.

DEAR MR. OWENS:

I beg to acknowledge the receipt of your letter of April 8th in which you are so good to inform me of the award of The Franklin Medal to Sir James Dewar. It is naturally a great pleasure to me to learn of the decision of The Franklin Institute to confer this honour upon Sir James Dewar, and I trust you will be good enough to convey to the members of the Institute the appreciation which I am sure will be generally felt in Great Britain at this recognition of the work of a British man of science.

I fear that it will not be possible for me to accept your kind invitation to visit the Institute on May 21st in order to receive the Medal and Certificate for Sir James, as I shall have left this country by the date in question unless some unexpected alterations should be made in my plans. The Embassy will, however, be only too glad if they can be of service to you for forwarding this Medal to London.

Believe me,
Very truly yours,
(Signed) READING.

R. B. OWENS, ESQ.,
Secretary, The Franklin Institute,
Philadelphia,
Pennsylvania.

WESTERN UNION CABLEGRAM.

LONDON, April 21, 1919.

The Secretary Major Owens,
The Franklin Institute (15 S. 7st),
Philadelphia.

Convey to Council grateful appreciation for award of The Franklin Medal. Regret cannot receive it personally owing to poor health. Will write. Accept personal regards.

DEWAR.

THE FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA
OFFICE OF THE SECRETARY Philadelphia

APRIL 25, 1919.

Major General James Douglas McLachlan,
Military Attaché, British Embassy,
Washington, D. C.

SIR:

I have the honour to inform you that The Franklin Institute has awarded to Sir James Dewar, of the Royal Institution, London, England, The Franklin Medal, founded for the "recognition of those workers in physical science or technology, without regard to country, whose efforts in the opinion of the

Institute have done most to advance a knowledge of physical science or its applications." The award is minuted as follows:

> "That The Franklin Medal be awarded to Sir James Dewar, of London, England, in recognition of his numerous and most important contributions to our knowledge of physical and chemical phenomena, and his great skill and inventive genius in attacking and solving chemical and physical problems of the first magnitude."

The medal and accompanying certificate are being prepared, and I am requested, on behalf of our management, to extend to you a cordial invitation to come to the Institute on the afternoon of Wednesday, May 21st, to receive this medal and certificate from our President, on behalf of your Government, for Sir James.

A second medal has been awarded to Major General George Owen Squier, Chief Signal Officer, U. S. Army, in recognition of his scientific and technical achievements, especially with relation to communications.

You and Major General Squier will be asked to be guests of honor at a dinner to be given on the same evening, but in this connection our President, Dr. Walton Clark, will communicate further with you.

I am,

Respectfully,

(Signed) R. B. OWENS,
Secretary.

RBO:S

THE MILITARY ATTACHÉ
BRITISH EMBASSY

WASHINGTON, D. C., 28 April, 1919.

MY DEAR MR. OWENS:

Owing to my temporary absence from Washington on duty your letter of the 25th of April has only just reached me. I am very pleased to learn from it that The Franklin Medal has been awarded to Sir James Dewar, of the Royal Institution, London, England; and I am very flattered at being invited to receive from your President on behalf of the British Government the medal and certificate awarded to Sir James Dewar.

I much regret that Lord Reading, the present British Ambassador, sails for England on the 3rd of May, and is therefore unable to represent the British Government at Philadelphia on the 21st of May. I should esteem it a favour if you would convey to the President and Members of the Franklin Institute my high appreciation of the honour they have done me in selecting me to take Lord Reading's place on the 21st of May, and my grateful acceptance of their kind invitation.

With the assurance of my high esteem,

I am,

Yours very sincerely,

(Signed) JAMES D. MCLACHLAN,
Major General.
British Military Attaché

MC/P

R. B. OWENS, ESQ.,
THE FRANKLIN INSTITUTE,
Philadelphia, Pa.

PROGRAMME OF MEETING, MAY 21, 1919.

Presentation of The Franklin Medal to Major General James Douglas McLachlan, C.B., D.S.O., on behalf of His Britannic Majesty's Government for Sir James Dewar, D.Sc., LL.D., F.R.S.; Jacksonian Professor of Experimental Philosophy, University of Cambridge; Fullerian Professor of Chemistry, Royal Institution, London.

Presentation of The Franklin Medal to Major General George Owen Squier, Ph.D., Chief Signal Officer, United States Army.

Address:

"Some Aspects of the Signal Corps in the World War." By Major General Squier.

PRESENTATION OF THE FRANKLIN MEDAL TO SIR JAMES DEWAR AND MAJOR GENERAL GEORGE OWEN SQUIER.

IN calling the meeting to order the President of the Institute announced that the business of the meeting would be the annual presentation of the Institute's highest award, The Franklin Medal, in recognition of distinguished scientific and technical achievement, and recognized Dr. Harry F. Keller, who made the following statement relative to the work of Sir James Dewar:

Mr. President: It was at the May meeting of the Institute, 1914, that you presented the first impressions of the beautiful Franklin Medal to two illustrious men of science. This precedent has since been followed, and so we meet here today for the fifth time to pay our tribute to a pair of savants who in the judgment of the Institute have done most to advance our knowledge of physical science. As chance would have it on the present occasion the time could not have been chosen more happily; for in these days of May our Nation is jubilantly celebrating the return of her heroic sons and exultantly looking forward to the early conclusion of a glorious peace.

And I regard it as a very special and rare privilege, Mr. President, to have been asked to present to you as The Franklin Medalists two scientists who have not only made abundant contributions to our knowledge of physical phenomena, but who also by their great achievements have so conspicuously helped our country and its associates in winning the war. It seems, moreover, peculiarly fitting that one of the medalists should be a native and citizen of Great Britain, while the other was born and bred an American.

In accordance with its established custom the Committee on Science and the Arts has based its recommendations upon the recognition of work in both pure science and applied science, without, however, drawing a sharp line of demarcation. For, well-defined as this line appeared before the war began, it has been largely obliterated during the years of the war, when scientists made patriotism their highest aim, and unstintingly gave their services to their Governments, accomplishing feats which in other times would have seemed impossible.

The first of these medals is to be conveyed to a man whose name for two generations past has been one to conjure with in the camps of chemists and physicists. Sir James Dewar is universally recognized as one of the foremost leaders in the two branches of physical science, and the great wealth of contributions he has made to both includes discoveries and inventions of the highest value and in many fields of research.

Like so many famous men of science, he is a native of Scotland. Born at Kencardine-on-Forth, September 20, 1842, he received his training in the sciences at Dollar Academy and the University of Edinburgh. It was in the latter institution, in 1863, that he became assistant to Sir Lyon Playfair, the Professor of Chemistry. In 1868 he spent a few months at the University of Ghent, Belgium, where the brilliant researches of A. F. Kekulé were then attracting the attention of all workers in organic chemistry.

The scientific career of Sir James Dewar presents itself as a long, unbroken, and almost unparalleled series of triumphs in experimental research. It would be difficult indeed to name another investigator of our time who has to his credit a like rich harvest of discoveries and inventions. The time allotted me here is scarcely sufficient to permit even the briefest reference to his more important achievements. He is one of the few great scientists who have not been hampered in devoting their careers entirely to experimental inquiry. As I have already stated, the subjects of his pursuits lie in the fields of chemistry and physics, or on the border-lands of these sister sciences.

In the earlier years of his career he directed his attention mainly to the coal tar bases, and among the researches he made at this time those on pyridine, quinoline, and their numerous derivatives, were the most notable and important. With the experience

gained in this line of work he then engaged in the study of modern high explosives, and as a member of the Government Explosives Committee, he invented, jointly with Sir Frederick Abel, the smokeless powder, cordite, which is the powder used by the British Government.

But the most extended and most fruitful researches of our medalist are undoubtedly those in which the effects of low temperatures were brought to bear on the properties of matter. Not only was he one of the pioneers but in many respects also the most successful experimenter in the field of low-temperature research. He was the first to liquefy atmospheric air on a larger scale and it was he also who made liquefied gases, like oxygen, nitrogen, hydrogen and fluorine, available for scientific use. By evaporating liquid hydrogen under reduced pressure he succeeded in obtaining solid hydrogen. Most remarkable results were obtained by subjecting various substances to very low temperatures. Thus liquid oxygen was found to be strongly magnetic; pure metals at temperatures approaching absolute zero became almost perfect conductors of electricity; and by the use of charcoal as an absorbing agent for gases at extremely low temperatures the highest vacua were attained. By means of charcoal also gases like hydrogen, helium and neon were separated from the air, and in this way highly important information was obtained as to the constitution of atmospheric air.

The inventive genius of Sir James Dewar was strikingly shown in the construction of the new and very elaborate devices employed by him in the liquefaction and solidification of various gases. The silvered vacuum-jacketed vessel, the Dewar flask, is now manufactured on a large scale for keeping hot and cold liquids for long periods of time under the name of Thermos bottles.

The great versatility and resourcefulness of Sir James and his prodigious capacity for work are further reflected by the great number of researches in which he was associated with other distinguished scientists. They embrace a great variety of subjects in the domains of inorganic and organic chemistry, physics and physiology. Among them special mention should be made of the very extended researches in spectroscopy with George Downing Liveing; the difficult and successful experiments on the liquefaction of fluorine with Henri Moissan; the determination of atomic and molecular constants with William Dittmar and with

Alexander Scott; and studies on the physiological action of light and various chemical agents with John Gray McKendrick.

Advancing years have not impaired Sir James' enthusiasm for research, nor his skill and cunning as an experimenter. In recent years he has made many notable contributions to our knowledge of the radioactive substances, and has successfully solved also various problems of capillarity and surface tension. Truly sensational were his experiments with the stable and long-lived soap bubbles blown in a cryophorus vacuum or in perfectly pure air. They were photographed by him in their natural colors and in various stages of development, appearing uniformly black when the final stage of tenuity was attained.

That the scientific institutions and societies of all countries should have vied with each other in lavishing their highest honors upon a man who has done such marvelous things goes without saying. I shall not attempt to enumerate the many positions of trust and honor he has graced with his incumbency, nor the medals, prizes, and degrees that have been bestowed upon him. We rejoice that as the last but not least of the long list we may now add The Franklin Medal, and that this award is so highly appreciated by the recipient. Unfortunately, as he has cabled the Institute, he is prevented by illness to receive it in person, but we are honored by the presence of a distinguished representative of the British Government, who on behalf of the latter will receive the medal for Sir James Dewar. I have the honor, Mr. President, to present to you Maj.-Gen. James Douglas McLachlan, C.B., D.S.O.

The President, in presenting The Franklin Medal to Major-General McLachlan, said:

General McLachlan, the members of The Franklin Institute are appreciative of the distinction conferred upon this meeting by the presence of a representative of the Government of Great Britain; and we thank you personally, Sir, for coming to have a share in our simple ceremony.

The Franklin Institute, having awarded to your distinguished countryman, Sir James Dewar, in recognition of his services to mankind rendered in the field of science, The Franklin Medal and Diploma, and a certificate of Honorary Membership in The Franklin Institute, it becomes my duty and privilege to present to

you this Medal and these documents for transmission to Sir James through the State Department of your Gracious Sovereign. These awards constitute the highest honor in the gift of the Institute.

In accepting the medal for Sir James Dewar, Major-General McLachlan said:

Mr. President, Members of The Franklin Institute, Ladies and Gentlemen: I much appreciate the honor that has been done me in inviting me to accept on behalf of The British Government The Franklin Medal awarded by The Franklin Institute to Sir James Dewar. And I should like to express to you how sorry Lord Reading was that he had to sail for England before the date fixed for this ceremony. His commanding presence and his eloquence would have been a much finer means than any words of mine for expressing the pleasure and gratification of the British Government and the British nation at the signal honor done to British Science by the award of this medal to Sir James Dewar. For this is the first time that this high distinction has been awarded to a British subject, and for that reason both I and my country are indeed proud today.

The work and scientific achievements of Sir James Dewar have been set forth in detail by Dr. Harry F. Keller, and I shall not repeat them. But in the minds of soldiers the name of James Dewar will always be associated with two things, firstly, the Thermos flask which he invented, and secondly, the smokeless explosive Cordite, of which he and Sir Frederick Abel were co-inventors.

As a soldier and a Scotsman it gives me great pleasure to receive for Sir James Dewar this medal. For he is a Scotsman and a countryman of mine, and it was in Edinburgh that he first began his studies of chemistry under Lord Playfair.

And another reason why I am glad to have an opportunity of speaking to you today is this: This war has shown how absolutely essential it is to make the fullest use of the chemical, metallurgical, manufacturing and engineering resources of a country in order to ensure success in war. To ensure success in modern warfare all the resources of the country must be utilized strictly for war purposes. If you will look through the membership list of The Franklin Institute you will see how large a number of the members gave their services to the Government

at a time when technical experts such as they were urgently needed. I select two names, the first to come into my mind, that of General Atterbury, who served as Director-General of Railways in France, and that of Mr. Vauclain, Vice-President of the Baldwin Locomotive Works, who did such splendid work on the War Industries Board in Washington and with whom I was constantly in close touch during the war. I know that many other members of The Franklin Institute did equally good work, but I merely mention these two names as typical of the work done by members of The Franklin Institute during the war; and it is of great value to any Government to have an Institute such as this whose members have the technical knowledge of chemical, metallurgical, engineering and manufacturing questions which is indispensable for the adequate carrying on of a great war.

Lastly, I am very glad to have the chance of witnessing the presentation of the medal of The Franklin Institute awarded to my old friend and companion in arms Major-General Squier. It has been my good fortune to know General Squier for over eight years, both in this country and in England, and in addition to the other bonds of friendship that unite us we both had the good fortune to serve in France with the original Expeditionary Force in 1914. For that reason I am particularly glad to be here this afternoon.

I take this opportunity of expressing to you the thanks of Sir James Dewar and of Great Britain for the honor thus conferred for the first time on a citizen of the British Empire. May it cement still further the friendship between the two great English-speaking nations, and may we, together with those great Nations alongside of whom we have fought and won the great struggle in defence of the liberties of the world, may we, I say, all continue to work together in the arts of peace and civilization as successfully and whole-heartedly as we have fought together in the recent great war.

Dr. Keller was again recognized, and presented the following statement of the work of Major-General Squier:

Mr. President: It is a well-known fact that under the stress of great national crises individuals are often stimulated to almost superhuman performance, and that tasks which in normal times it would require decades to accomplish, are then done, and well

done, by such men in a few months or years. The great war which has just come to an end has furnished many instances of this sort, but few so remarkable as that of the scientist to whom you are about to present the other impression of The Franklin Medal. By natural inclination as well as by training a military man and a scientist, he achieved such distinction in both capacities that at the time when our country entered the great war he was chosen for the gigantic dual task of building up our Air Fleet and of providing the field telephone and wireless communications for our armies. How nobly and well he acquitted himself of these responsibilities I need not tell you or an audience such as this. I cannot refrain, however, from expressing the thrill of pleasure I experience in presenting to you for the highest award of the Institute a man who has so magnificently served our Country in the great crisis.

Our medalist, Major-General George Owen Squier, Ph.D., is still in the prime of life, and we may well hope and expect that in the years to come he shall gather many laurels to add to those he has won in the war and before it. He was born at Dryden, Mich., on March 21, 1865. He received his military training at the U. S. Military Academy, West Point, N. Y., and it was there that he first showed his decided bent toward mathematical and scientific studies. After his graduation in 1887 he was appointed second lieutenant in the Artillery, and shortly afterwards sent for duty to Fort McHenry, at Baltimore, Md. I venture to say that no assignment could have been made more welcome to the young officer who so ardently aspired to be a physicist. For, close at hand, at the Johns Hopkins University, the chairs of physics, chemistry and astronomy were then held by a trio of the most eminent exponents of physical science, *viz.*, Henry Rowland, Ira Remsen, and Simon Newcomb. And he lost no time in taking advantage of his opportunities, nor were the teachers slow in recognizing the exceptional ability and great promise of their soldier-student. In all three cases the relations between teacher and student were destined to grow into lasting friendships, while the young officer was laying the foundations for those inventions which have since made him famous as a physicist.

His first important contribution to science was a research on "Electrochemical Effects due to Magnetization," published in

1893. Four years later he wrote, jointly with Dr. A. C. Crehore, of Dartmouth, a mathematical paper entitled "Currents in Branches of a Wheatstone's Bridge," and about this time he engaged, partly by himself, and partly in conjunction with Dr. Chehore, in a series of investigations relating to applications of physics to military service. Among the numerous important results of these were the invention of a New Range and Position Finder and the Synchronograph. The latter marked a great step forward in the rapid transmission of intelligence, being based on the use of the alternating current with the polarizing photochronograph as receiver. But this was only the beginning of a great series of achievements by which our medalist advanced and improved the methods of telegraphy and telephony. The "wired-wireless," first proposed by him in 1911, has proved, especially in military field operations during the war, to be invaluable as a means of sending intelligence and commands. As the name implies, it is a method of telegraphing or telephoning by means of electrical waves guided by wires. In this way as many as a half dozen messages may be sent *along* a telephone wire, but *outside* of it, at the same time, and without interfering with the use of the wire for ordinary service. The messages, however, must be tuned to different frequencies and be received by separate receivers. One great advantage of this system is that the waves will still travel along the wire when it is broken and jump gaps in it of fifty feet and more. The "wired-wireless" method of multiplex telegraphy and telephony has recently been adapted and developed for commercial purposes and has proved especially useful on long open wire lines. During the last few years our medalist has devised a new method of ocean cabling which is now in successful operation, effecting a very considerable increase in the capacity of the existing cables. This remarkable stride in cable transmission was made by substituting for the cable "curve," made by opening and closing the circuit, a single-phase alternating current of the sine wave type, operating with the Morse code.

The wire and wireless inventions made by General Squier are bewildering in their variety and number. They extend over the entire range of the transmission of intelligence on land, under the sea and in the air. His studies on the absorption of electromagnetic waves by living organisms led, among other things, to the use of trees as antennæ in wireless telegraphy and the con-

struction of a new listening device, the "floraphone." It was he also who laid the inter-island cable in the Philippines, in 1900, and who drew up the first specifications of a military airplane ever issued by any government. What he did in building up our air fleet and as Chief Signal Officer in our army is too well known to require any commentary at this time and before this audience.

Nor is it necessary for me to recite here the many steps of his promotion from second lieutenant to his present rank of Major-General, which have attended his most brilliant and eventful career in the Army.

Until a few days ago we had confidently expected that General Squier would be with us on this occasion. I know he was looking forward to it with genuine pleasure, but he has quite unexpectedly been ordered abroad. In his absence Dr. F. P. Keppel, Assistant Secretary of War, has kindly consented to come here from Washington to receive the Franklin Medal for him. I have the honor, Mr. President, to introduce to you Dr. Keppel.

The President then said:

Dr. Keppel, the members of The Franklin Institute are appreciative of the honor conferred upon this meeting by the presence of a representative of the War Department of our National Government; and we thank you personally, Sir, for coming to have a share in our simple ceremony.

The Franklin Institute, having awarded to our countryman, Major General George Owen Squier, in recognition of his services to our country and to humanity, rendered in the field of science, The Franklin Medal and Diploma, and a certificate of Honorary Membership in The Franklin Institute, it becomes my duty and privilege to present to you this Medal and these documents for transmission to General Squier through the War Department of our National Government. These awards constitute the highest honor in the gift of the Institute.

Dr. Keppel, in accepting the medal for Major General Squier, expressed the pleasure which the War Department felt in having the life-work of General Squier recognized by the highest award in the gift of the oldest institution in America devoted to the development of physical science and its application, and to the encouragement of those whose researches and inventions have served as milestones in the progress of civilization.

Colonel M. McK. Saltzman, Acting Chief Signal Officer, then read the following paper for the medalist:

SOME ASPECTS OF THE U. S. SIGNAL SERVICE IN THE WORLD WAR.

BY

GEORGE OWEN SQUIER, Ph.D.

Major-General, Chief Signal Officer U. S. Army.

IT is with the keenest regret that I find it impossible to be present at the Hall of The Franklin Institute on the afternoon of the 21st of May to receive at the hands of our President The Franklin Medal.

Nothing short of a sudden call for overseas service, from the Commander-in-Chief himself, would have prevented me from being present in person to receive this signal honor from our venerable Institution.

Had I been present you would have expected me, no doubt, to give very briefly the underlying principles which have guided those of us in authority in the making of that part of our expeditionary forces which has to do with the transmission of intelligence in all of its ramifications of personnel and matériel.

This is not the time nor the place to speak in detail of that great enterprise. In the fulness of time these details will be preserved as they should be in the archives of our country. It manifestly can be done only when we can add to the accomplishments of this side of the Atlantic the details of the work of the Signal Corps in actual combat and in the equally important network of communications behind the lines which has been built up not only in France but in England, Italy and Russia and wherever American soldiers have been sent for duty.

It would be quite impossible to mention either the names or the accomplishments of the 2712 officers and the 53,277 men who have been engaged in this great work. Where names are mentioned it is purely incidental to illustrate a point.

This famous Institute itself contributed a conspicuous part in this enterprise. In the early days of the war this Institute for a time was turned into a veritable recruiting station for the Signal Corps, and some 2000 officers and men were by this means available to the Signal Corps, thus gaining most precious time.

The importance of inter-communication in warfare cannot well be exaggerated. The element of time is a controlling one in strategy and tactics, and as the distances become greater the electrical method of inter-communication surpasses all others in

increasing ratio. Unity of Command, which the Allies were so slow in realizing, can reach its full value only when the most perfect system of inter-communication is established and maintained between general headquarters and the larger units and between these and the smaller units to the man on the firing line.

The enormous size of modern armies and vast terrain over which they must operate only accentuates the importance of the intelligence transmission system.

History records from the earliest times the development step by step of methods of signaling. It is known, for instance, that the Indians who inhabited this continent prior to its discovery by Columbus had certain efficient methods of signaling unknown to us at present.

As civilization has progressed science has been called upon at each step to contribute additional means of communication between individuals or groups.

Undoubtedly the most efficient method of signaling yet devised is the spoken word which we employ hourly to signal our thoughts in every shade of their meaning.

The telephone art, which stands to-day as a monument to American genius, and every essential feature of which can be traced to American origin, is efficient over all others for the fundamental reason that it vastly extends the reach of the human voice and permits the use of language directly in signaling. This means that practically every individual is an expert signalman, and in the United States there is no region so remote but that it may not be joined at present to any other region by direct speech.

The advances in radio telephony and telegraphy where the ether of space becomes a common "party line" for all, and particularly the linking up of these ether circuits to the great wire systems of the world, protends the day which I believe is not far distant, when we can reach the ultimate goal so that any individual anywhere on earth will be able to communicate directly by the spoken word to any other individual wherever he may be.

Nor is this linking up of methods of communication restricted to the surface of the earth. To a limited extent we can communicate from distant points above the earth to points beneath the surface of the earth or of the ocean. To-day we are talking directly from the high-speed airplanes above the clouds to the wire systems of the country and ships at sea also can speak from mid-ocean to land stations of the wire system.

It is possible, for instance, for the President of the United States to exercise his functions during residence in Europe which would have been utterly out of the question a few years ago. Indeed, the time is not far distant, it is believed, when the President of the United States may address from the White House practically the entire American people assembled in their respective localities throughout the country to receive his message by his own voice.

The radio lighthouse, which shall mark the aerial highways throughout the land and serve as beacons for the guidance and location of aircraft on every voyage, is an accomplished fact, and these will multiply rapidly as each city and town of the country is brought within the expanding net-work of public and municipal flying grounds.

These lighthouses have certain advantages over the normal lighthouses in that their ranges may be much greater, and they are not invisible in the daytime nor obscured by fog and mist.

Surely no development can surpass in wonder and amazement the accomplishments of radio telephony and telegraphy and certain associated subjects now being realized every hour.

We are on the threshold of the inauguration of what is called the League of Nations and drastic limitations to the enormous burdens which nations in the past have carried in the creation and maintenance of military armaments will, it is hoped, be imposed. The practical execution of the provisions of the League of Nations from the military, economical, social and diplomatic standpoints will depend, it is believed, very largely upon the creation, expansion and maintenance of the most perfect interlinked network of inter-communication, literally covering the land, sea and air. Such a perfect system will be the cheapest and most certain adjunct to effectively carrying out the provisions of this League, and will contribute to a better understanding between nations as will no other agency or instrumentality.

On April 6, 1917, the Signal Corps of the Regular Army consisted of 55 officers and 1570 men, and the problem confronting the Corps was how to provide in the shortest possible time for an installation in Europe as well as in the United States, which should extend from every factory door and training camp throughout the United States to the front line trenches in France.

The Signal Corps is a small compact service ranging from 2½ to 4 per cent. of the Army, which in a peculiar sense serves

all branches of the Army as perhaps no other service does. To illustrate, if at any time prior to the signing of the armistice we were to subtract from the American Army the Signal Corps in its entirety for a single hour, the whole military machine would utterly collapse. This is believed not to be the case to the same extent for any other equal per cent. of the Army. This merely means that this small percentage, which may be called the nervous system of the body of the Army, must be made both in personnel and matériel as efficient and perfect as possible.

Nothing should be left undone which contributes in any manner to the creating and maintaining of the highest efficiency in this small percentage of the Army which adds this vital service.

The advance in the science and art of electrical communication has reached a point where it may be said that the Signal Service stands to-day as a distinctly technical service second to none in the Army.

Realizing the utter unpreparedness of this country at the time we entered the war and having been fortunate enough to have been in Europe with one of the allied armies covering a period of two years of the war, I realized that the only hope of an adequate Signal Service in the shortest possible time was to so arrange matters that the very best trained men in this country already engaged in the telephone, telegraph and electrical industries should be made available forthwith after the outbreak of war.

Our problem was a different one in this country from that of our Allies where the telegraph and telephone systems are already in control of the Government.

Realizing the importance of this, sometime in January, 1917, as I remember it, prior to the entrance of this country into the war, I went to New York and had an informal conference with Mr. Theodore N. Vail, President of the American Telephone and Telegraph Company; Mr. Newcomb Carlton, President of the Western Union Telegraph Company, and in particular with my friend Colonel John J. Carty, in which the general outlines of the procedure in case we entered the war were talked over and arranged.

The problem was, How could we pick from these organizations and other similar utilities the men and equipment needed immediately without crippling that essential service in the United States, where additional demands would be made in the vast industrial preparations required at home also?

Manifestly this could be done only by thorough coöperation between the Government and the guiding heads of these utilities.

The first move therefore made upon the outbreak of war was the commissioning of four or five of the leading engineers and executives in the commercial telephone and telegraph companies of this country and these in turn were charged with the selection and organization of the trained personnel to be sent immediately abroad to start the work while the new army could be trained in this country. These engineers and executives, instead of being brought to Washington in the early days of the war, were left directly at their offices, where they had every facility organized, and they took their orders from the Signal Office in Washington. With the loyal coöperation of the companies themselves it was possible to send to Europe in the first months of the war twelve battalions of the best trained men this country could produce. Each one of these organizations was composed of officers and men who were already technically trained and whose conduct and character were vouched for by the organizations from which they came.

In the meantime, of course, the machinery for a large number of technical schools was set in motion which later produced the flow of field and telegraph battalions required for the combatant troops.

If the Chief Signal Officer had brought this first group mentioned above directly to Washington, as would have been the usual procedure, the time which it would have taken, under the congested conditions necessarily then existing in the War Department, to establish these officers and equip them with the office machinery required, and learn the intricacies of army routine, would have caused the Signal Corps to lose a great deal of valuable time in getting the initial start in France.

During the early months of the war, therefore, these officers in the uniform of their country, installed in their regu'ar offices, with the full machinery at their disposal, represented for a time the United States as well as their former employers, and through the hearty coöperation and loyal support of all hands the Signal Corps was enabled to get under way with the ablest and most experienced technical men in the country in the shortest possible time.

It is difficult to realize to what extent specialization has reached under the impetus of war in the matter of electrical

intercommunication. The mere enumeration of the types of specialists now required by the Signal Corps is a formidable one. In addition to regular special troops in the line branches of the Army this service demands highly trained specialists as follows:

Telephone and telegraph engineers
Traffic and plant experts
Operators both male and female, speaking French, English and German
Installers and maintenance experts
Telephone and telegraph repeater experts
Printing telegraph mechanicians
Traffic supervisors and test-board men
Traffic and wire chiefs
Linemen
Switchboard repairers and installers
Radio engineers, constructors and operators
Electrical research experts
Meteorologists
Photographers—both still and motion
Pigeon fanciers
Optical experts and field glass repairmen
Instrument makers and repairers
Shop practice experts and oxy-acetylene welders
Production experts
Gasoline and motor transport experts
Motorcyclists
Chauffeurs
Dry and storage battery experts
Storehouse managers
Cable experts and operators
Draftsmen

RESEARCH AND DEVELOPMENT.

In no branch of the military establishment is the need for continual research more necessary than in the Signal Corps of the modern army. Scarcely a single piece of technical apparatus that was regarded as adequate at the beginning of the war is to be found in the Signal Corps equipment at the time of the signing of the armistice. Strong research departments were founded both in France and in the United States and the best men of the country available were assigned to this work. Many of these men were taken from universities and colleges and electrical, chemical, physiological and mechanical specialists were set to work on both sides of the Atlantic to devise new means of supplementing the methods of signaling and associated subjects. In engineering development the demands grew to the proportion of a large indus-

trial plant. The entire facilities of the Bureau of Standards were requisitioned on a large number of special problems and the principal personnel of the Weather Bureau were used in the newly established meteorological service.

It was soon realized that a special laboratory devoted exclusively to development work and entirely independent of the commercial laboratories, such as the Western Electric Company and the General Electric Company, would be needed, and a special laboratory fully equipped for radio development was established at Little Silver, New Jersey, which grew to be one of the largest in the world. Recently this site has been purchased for the permanent use of the Signal Corps and the experience of the present war has clearly shown the necessity for an institution of this sort where trained specialists may devote their entire energies to the new problems constantly arising in the extension of methods of intercommunication now appearing as never before.

The Science and Research Division of the Signal Corps was established in Washington and a mere enumeration of the number of problems which this Division was called upon to investigate and develop shows to what extent all branches of science were drawn upon to perfect this service.

TRAINING OF PERSONNEL.

It was not possible to take men from the general draft and train them as efficient telephone and telegraph men within the very short time that could be allotted for training, and hundreds of men assigned directly to Field Signal Battalions from the general draft had to be turned back again. The plan eventually worked out was to obtain 75 per cent. of all Signal Corps personnel required, from enlisted men who had completed the course of instruction laid down by Signal Corps schools. These schools were established at the principal colleges, universities and technical schools throughout the country. In addition five large training camps were established as follows:

Camp S. F. B. Morse
Fort Leavenworth
Camp Alfred Vail
Franklin Cantonment
College Park, Maryland

The curriculum was established for these schools and standardized for all, which included a thirteen weeks' technical course.

As to the results obtained in the selection and training of personnel, the following statement was made by Mr. Daniel W. LaRue, Chief Psychological Examiner, upon the completion of his work at the Signal Corps Cantonment, Camp Meade, Md.:

"These facts substantiate what has been found in other camps, that the Signal Corps personnel as a whole have the highest average intelligence as far as the Army psychological examinations can determine."

EQUIPMENT.

The extent of equipment required by a modern army for Signal Corps purposes is beyond what anyone could have dreamed. As an example, a single order for a certain kind of insulated wire was in sufficient amount to extend 14 times around the earth. The cost of Field Glasses alone exceeded $40,000,000, and Wrist Watches for Signal Corps operators alone reached a total in excess of 43,000 watches. Over a million batteries were produced, and 285,000 Vacuum Tubes for radio amplifiers. Over 100,000 telephones for field use alone were necessary, and over 200,000 pliers for use in line construction work. Over 8000 of one single type of Radio apparatus was produced and shipped to France.

The above items constitute but a few of the 267 which are furnished to various branches of the Army as Unit Equipment. In addition to these there are over 2000 items for use by the Special Services and in maintaining communication in the Zone of Supply.

The above brief outline of the quantities of modern Signal Equipment required for the conduct of war as it is now understood teaches above all other things one lesson in organization, which is, that the Signal Corps officer, like a medical officer, must make the Signal Service his life work. Previous to this war the Signal Corps of the American Army was organized by detail from the infantry, artillery, or cavalry, for a period of four years. Having in mind the services which are rendered to each and all branches of the army by this small group of specialists, it is clear that in any plan for reorganization we must first select with great care the young officers for this service and then give them the best training to be found in the country for their work, since it is only by continuous application and study that the Signal Officer can hope to maintain his efficiency.

The supreme test of the Signal Corps, as of all other branches

of the Army, is always to be found in the performance of its tasks under the actual tests of battle and in the military areas which supply and maintain the combatant troops. I cannot better close these brief observations of the Signal Corps than by quoting a letter from General Pershing, the Commander-in-Chief, issued and published to the American Expeditionary Forces under date of February 19, 1919:

> "Now that active operations have ceased, I desire to congratulate the officers and men of the Signal Corps in France on their work, which stands out as one of the great accomplishments of the American Expeditionary Forces—the result of a happy combination of wise planning and bold execution with the splendid technical qualities of thousands of men from the great commercial telephone, telegraph and electrical enterprises of America. It is a striking example of the wisdom of placing highly skilled, technical men in the places where their experience and skill will count the most.
>
> "Each Army Corps and Division has had its full quota of Field Signal Battalions which, in spite of serious losses in battle, accomplished their work, and it is not too much to say that without their faithful and brilliant efforts and the communications which they installed, operated and maintained, the successes of our armies would not have been achieved.
>
> "While the able management of the directing personnel is recognized, it is my desire that all members of the Signal Corps, who, regardless of long hours and trying conditions of service, have operated and maintained the lines, shall know that their loyalty, faithfulness and painstaking care has been known and appreciated. In the name of the American Expeditionary Forces, I thank them one and all and send to them the appreciation of their comrades in arms and their Commander-in-Chief."

After the reading of the above paper moving pictures and lantern slides illustrative of A. E. F. Signal Corps activities were shown under the direction of Captain A. Bliss Albro, and a number of Signal Corps communication devices, such as T. P. S. sets, trench and airplane radio sets, etc., were exhibited by Captain E. F. Pernot.

Cements Producing Quick-hardening Concrete. P. H. BATES. (*Proceedings of the American Society for Testing Materials*, June 24–27, 1919.)—There have been prepared at the Pittsburgh branch of the Bureau of Standards certain cements which have the property of hardening very rapidly. These were made in a manner no different from that used in making Portland cement, but their composition differed very materially from the composition of the latter in that they consisted very largely of lime and alumina. These calcium aluminates, when they are very high in alumina, do not have a very marked rapid initial set, but do harden very quickly and therefore produce high early strengths. Some of the maximum strengths were 3145 pounds per square inch for 1 : 6 gravel concrete, tested in the form of a 6 x 12 inches cylinder, at the end of twenty-four hours, 6010 pounds per square inch at the end of seven days, and 8220 pounds per square inch at the end of one year.

Tests were also made on 6 x 12 inches cylinders in which the bonding material was "Sorel cement." These cements are produced by gauging light calcined magnesia with magnesium chloride solution. The fact that magnesium oxide when mixed with a solution of magnesium chloride will harden was possibly first known by Sorel in 1853; from him it has at least taken its more common name. Such a cement develops in twenty-four hours a strength approximately equivalent to that developed at the end of seven days by a similar concrete made with Portland cement. Both of these cements commend themselves for certain special uses where a quick-hardening concrete of high strength is required. Neither would be desirable where subject to the continued action of water. The Sorel cement alone is on the market at the present time.

Artificial Stone from Mica and Clay. ANON. (*The American Architect*, vol. cxv, No. 2268, p. 824, June 11, 1919.)—Mr. Chr. Ingvaldsen, of Saaheim, Norway, claims to have devised a process of making a practicable building stone by mixing finely divided mica with a just sufficient amount of clay or other substance of similar properties, to form a coherent mass, which is then shaped into blocks, plates, and other objects of any desired shape and size. These, it is learned, are then fired at a temperature just high enough to fuse the mass, the resulting stone having in general the same properties as natural mica.

If it be desired to produce stone having greater resistance to high temperatures the process is modified as follows: Instead of mica alone, a mixture of equal parts of mica and of crushed quartz, with just enough clay to act as a binder. The stones formed from this mixture are fired at a temperature high enough to secure the fusing of the mica. The result is a homogeneous mass not only highly refractory to heat, but capable of acting as an electric insulator.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A SIMPLIFICATION OF THE INVERSE-RATE METHOD FOR THERMAL ANALYSIS.[1]

By Paul D. Merica.

[ABSTRACT.]

THE use of stop-watches in taking inverse-rate curves in thermal analysis is described, and it is shown that they may be substituted for the chronograph, which is often used without sacrificing accuracy or sensitivity. One operator is able to record the successive time intervals for the inverse-rate curve, with their aid, and no time is subsequently required for the reading and counting of the chronograph record; the intervals so recorded may be plotted directly.

STRENGTH AND OTHER PROPERTIES OF WIRE ROPE.[2]

By J. H. Griffith and J. G. Bragg.

[ABSTRACT.]

Nature of Investigation.—The paper presents the results of tests upon 275 wire ropes submitted by American manufacturers to fulfill the specifications framed by the Isthmian Canal Commission in 1912. The samples were selected by government inspectors for acceptance tests of materials to be used at the canal zone.

The rope ranged in diameters from ¼ inch to 1½ inches, a few being of larger diameters up to 3¼ inches. Over half the specimens were plow and crucible cast steel hoisting rope of 6 and 8 strands, 19 wires each. The remainder were galvanized steel guy rope and iron tiller rope of 6 strands, 7 wires and 6 strands, 42 wires, respectively.

The investigation was made primarily to determine the tensile strengths of the ropes. Much of the experimentation was of a supplementary character—to determine the general laws of construction of the rope as the basis of the interpretation of their physical behavior under stress. A comparative analysis was made

*Communicated by the Director.

[1] Scientific Papers, No. 336.

[2] Technologic Papers, No. 121.

of the chemical constituents of steels, rope fibres and lubricants of plow steel ropes submitted by different manufacturers.

Methods of Tests.—The wires at the ends of specimens were "frayed out" to form a "broom." These were inserted into moulds, into which molten zinc was poured so as to form conical sockets for connection to the testing machines. Most of the tensile tests were made on a 600,000 pound Olsen testing machine, the ropes of large diameters being tested on the 1,200,000 pound Emery machine. Stress-strain measurements were made on over half the specimens. Numerous tests of individual wires were conducted in tensile, bending, and torsion machines. The strengths of the cables were studied in connection with their modes of construction, the strengths of their component wires, and the types of fractures which were presented.

Results of Measurements and Tests.—The homologous linear dimensions of the strands, wires, and fibre cores were found to vary in direct proportion to the diameters of the ropes. The diameters of the strands and fibre cores were generally one-third the diameter of the rope. The mean pitch or lay of the strands was 7½ diameters. The mean lay of the wires was 2¾ diameters. The mean diameter of the wires was expressed by the equation:

$$d = K\frac{D}{N+3}$$

d = diameter of wires.
D = diameter of rope.
N = number of wires in outer ring of wires of a strand.

$$K = \begin{cases} 1.0 & \text{for hoisting and guy rope.} \\ 0.8 & \text{for extra flexible 8 x 19 hoisting rope.} \\ .33 & \text{for tiller rope.} \end{cases}$$

The aggregate cross sectional areas of the wires was expressed approximately by the equation:

$$A = C^1 D^2 : C = \begin{cases} .41 & \text{for 6 x 19 plow steel hoisting rope.} \\ .38 & \text{for 6 x 19 cruc. steel hoisting rope.} \\ .38 & \text{for 6 x 7 guy rope.} \\ .35 & \text{for 8 x 19 plow steel rope.} \\ .26 & \text{for 6 x 42 iron tiller rope.} \end{cases}$$

It was found when the maximum loads determined from tensile tests were platted as functions of the diameters of the ropes that the curves bounding the lower frontiers of each zone comprising the observed values were in close agreement with similar

curves platted from the minimum strengths stipulated in the specification of the Isthmian Canal Commission of 1912. These strengths were also in approximate agreement with the standard strengths recommended in 1910 by the manufacturers from the results of their tests of cables similarly classified. The minimum strengths found from the present investigation are given by the following empirical equation:

$$\text{Load} = C\ 75000\ D^2$$

D = diameter of wire rope in inches.

$$C = \begin{cases} .9 \text{ to } 1.1\text{; mean value about } 1.0\text{; } 6 \times 9 \text{ plow steel cables.} \\ .8 \text{ to } .95\text{; mean value about } .9\text{; } 8 \times 19 \text{ plow steel and } 6 \times 19 \text{ cruc. cast steel cables.} \\ .3 \text{ to } .4\text{; mean value about } .35\text{; iron tiller and steel guy rope.} \end{cases}$$

The modulus of the rope calculated from stress-strain measurement was found to vary from 3,000,000 to 9,000,000 pounds per square inch, depending upon the diameter and class of cable.

Plow steel ropes were selected for comparative analyses of the constituent materials. In the chemical analyses the carbon content ranged from 64 to 96 per cent. with a mean of about 75 per cent. The manganese ranged from 25 to 68 per cent., the silicon from 11 to 24 per cent. The percentage of phosphorous and sulphur was relatively low. In certain cases the steel of the filler wires was softer than the main wires.

The fibres used in making the core of the rope were estimated as manila, jute, istle, mauritius, manila fibre alone being employed by certain manufacturers. The preservatives and lubricants on the cores were composed of wood and vegetable tars, petroleum products, and fish oil, the practice varying somewhat among the manufacturers.

There was a reasonable uniformity in the strengths and elongations of the wires from a particular cable, but a larger variation in the strengths of the wires from cables of different manufacturers. This was probably due to the fact that different grades of plow steel were used by the several manufacturers in meeting the provisions of the specifications.

The cables developed from 72 to 90 per cent. of the aggregate strengths of the wires. The upper limit of the ratio of the strength of a rope to the strengths of its wires was found from theoretical considerations to be 89.2 per cent. for 6×19 plow steel cables. The differences between the results of the theoretical analysis and

the practical tests were largely attributed to different strengths and degrees of ductility of the wires, this causing an unequal distribution of the load among the strands with over-stressing of certain strands near the point of failure.

NOTES ON THE GRAPHITIZATION OF WHITE CAST IRON UPON ANNEALING.[3]

By P. D. Merica and L. F. Gurevich.

[ABSTRACT.]

1. THE annealing or graphitization ranges of temperatures were determined for three different compositions used for car wheels. The temperature of initial precipitation of temper carbon for six hours of annealing was not noticeably affected by variation of sulphur content from 0.10 to 0.20 per cent. or by variation of total carbon content from 3.60 to 3.90 per cent., although the effect of greater carbon content is to narrow the temperature range within which graphitization is complete.

2. The temperature of beginning precipitation of temper carbon was about 830° for the six-hour period of annealing and about 725°C. for the forty-eight-hour period. The maximum allowable temperature therefore for the annealing or "pitting" of car wheels is about 725°C.

3. After complete decomposition of all free cementite by annealing at from 1000° to 1100°C. and cooling at equal rates in a laboratory electric furnace less graphite is found in a specimen cooled from 1100° degrees than in one of the same composition cooled from 1000°C. This indicates that graphite separates directly from solid solution upon cooling, when its nuclei are already present.

4. The fact that only 0.20 per cent. of combined carbon was found in some specimens after annealing at high temperatures and cooling slowly in the furnace would indicate either that the graphite eutectoid lies at much lower values of carbon content than has been previously supposed, that there is at these rates of cooling a direct precipitation of graphite eutectoid or that there is a formation of graphite from pearlite at temperatures directly below that of its formation.

[3] Technologic Papers, No. 129.

THE EFFECT OF RATE OF TEMPERATURE CHANGE ON THE TRANSFORMATIONS IN AN ALLOY STEEL.[1]

By H. Scott.

[ABSTRACT.]

COOLING curves taken on an air-hardening steel of the high speed tool steel type show two critical points on cooling from 920°C., one occurring at about 750°C. accompanied by the precipitation of the hardening constituent, the carbide, and the other on fast cooling at about 400°C., under which condition the carbide remains in solution as martensite. On cooling at intermediate rates both transformations are observed and the constituents, troostite and martensite, are detected by the microscope. A transformation is observed on the heating curves taken following a fast cooling which is manifested by an evolution of heat ending at about 645°C., and which represents the precipitation of the carbide held in solution by previous rapid cooling. The resolution of the carbide under these conditions occurs at a temperature some 10 to 15°C. higher than after a slow cooling.

The conclusions drawn support the twenty-year-old theory of Le Chatelier that martensite is a solid solution of carbide in alpha iron.

Photographic Evidences of Meter Readings. ANON. (*Electrical World*, vol. lxxiii, No. 1, p. 36, January 4, 1919.)—The Detroit Edison Company is using a special camera for taking "load test" meter readings to establish customers' demand charge. A regular meter reading camera was rebuilt so that now photographs are taken showing in the picture not only the meter reading but a watch dial with the time of reading and also the name and address of the customer.

The photographic readings have shown their value in a number of instances where differences of opinion have come up with regard to the correctness of load curves. For example, in a case where a customer raised an objection to his bill on the ground that readings were not taken exactly one hour apart, the production of an actual photograph of his meter with the time of taking shown on the same film satisfied him as to the correctness of the load test.

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[1] Scientific Papers, No. 335.

Testing Strength of Joint Glues. ANON. (*Forest Products Laboratory, Madison, Wisconsin, Technical Notes* No. F-16.)—In using glues for high-grade joint work, a knowledge of the strength of the joint is important. A method which is inexpensive, accurate, and suitable for use in a woodworking factory has not yet been developed. The following method, which is used at the Forest Products Laboratory, can be employed if a universal timber testing machine is available.

Two blocks of selected hard maple, about 1 inch by 2½ inches by 12 inches in size are glued together. After the glue has aged sufficiently they are cut into shear specimens and these are placed in a testing machine so that the base of the long half of the block rests on a metal seat. Pressure is then exerted on the short half, causing it to slide past the long half at the glued point. The pressure required to separate the blocks in this way is measured and the percentage of the area of wood surface torn out by the glue estimated.

If the failure occurs entirely in the glue, a measure of the strength of the glue joint is obtained, but if the failure is entirely or partly in the wood, as frequently happens, the full strength of the glue is not developed and the test may have to be repeated, using stronger blocks.

As the same method has been used in securing data on the strength of wood in shear, when the strength of glue has been determined, it can be compared with that of any wood whose average shearing strength is known.

The Forest Products Laboratory has made thousands of tests on specimens glued with casein and animal glues, and when properly used, these glues have shown shear values of 2400 pounds or more per square inch. Few commercial American woods average more than 2400 pounds per square inch in shearing strength, and the majority of them average less than 2000 pounds. Many glue tests have averaged as high as 3000 pounds.

How Much Water Should be Used in Concrete? ANON. (*Scientific American*, vol. cx, No. 15, p. 365, April 12, 1919.)—The Emergency Fleet Corporation, in connection with its work on concrete vessels, has developed an apparatus for testing the amount of water which should be used in concrete work. An open metal cylinder is employed resting upon a glass plate. This serves as a mold which is filled with concrete and smoothed off level on top. Then the cylinder is raised, leaving the concrete on the glass plate. If the mixture is very dry, the concrete will maintain its cylindrical form, but the wetter the concrete the more it flows out at the bottom, so that a measure of the consistency of the mixture can be obtained by measuring the height of the cylinder or cone of concrete after the metal cylinder has been withdrawn.

NOTES FROM NELA RESEARCH LABORATORY.*

NOTE ON THE DISTRIBUTION OF ENERGY IN THE VISIBLE SPECTRUM OF A CYLINDRICAL ACETYLENE FLAME.

By Edw. P. Hyde, W. E. Forsythe and F. E. Cady.

A KNOWLEDGE of the distribution of energy in the visible spectrum of an acetylene flame has become important within the last few years through the use of this flame, in cylindrical form, in investigations of the visibility of radiation. It can be shown by computation that the data on acetylene published by Coblentz form a curve in the visible spectrum which will not agree with that of a black body at any temperature to better than 7 or 8 per cent. As this would mean that no color-match could be obtained and as previous experience of the authors had led to the conclusion that the energy curve of acetylene differed in shape from that of a black body only in the extreme red, a short investigation was undertaken to verify this conclusion.

Tungsten lamps whose current color-temperature relation was carefully determined in this laboratory were sent to the Eastman Kodak Company and to the Bureau of Standards with the request that they be compared with the acetylene flame and the current for color match be found. The results gave an average value of 2360° K. ± 10° K., and neither laboratory reported any difficulty in obtaining a match in color. However, the Bureau of Standards reported a difference amounting to about 75° K. between the flame as given by the Eastman standard burner and that given by the "Crescent Aero" burner, the latter being higher.

The spectral distribution of the flame was measured by means of a spectrophotometer and a spectral-pyrometer and the results gave a curve agreeing within the limits of error with that of a black body at 2360° K. In the extreme red, beyond 0.70μ there was indication of a higher emissivity for the acetylene. A photographic method gave results corroborating those just mentioned.

A test of the sensibility of the color match method to show differences in the spectral energy curve, showed that if two spectral curves matched at 0.5μ and 0.7μ and differed by as little as

* Communicated by the Director.

4 per cent. in the middle of the spectrum, the two light sources could not be made to match in color.

In conclusion, it is recommended that the relative emission intensities of a cylindrical acetylene flame, at least for that type represented specifically by the Eastman standard burner and for the wave-length interval from 0.4μ to 0.7μ, should be taken as identical with those of a black body at 2360° K.

CLEVELAND, OHIO, June, 1919.

American Peat Industry. ANON. (*U. S. Geological Survey Press Bulletin*, June, 1919.)—The output of crude peat in the United States in 1918 far exceeded that of any preceding year and the general increase, which was stimulated by the war, was shared by practically all branches of the industry. Though extensively used as fuel in Europe and widely known in the United States as a potential source of heat and power, peat has been unable in most parts of the country to compete with coal and many peat operators have therefore directed their attention to the utilization of peat in agriculture with gratifying results.

Use of Peat in Agriculture.—Peat fertilizer was first marketed in commercial quantities in 1908, and stock-food peat in 1912, and though there is still some prejudice against the use of these products the agricultural branch of the peat industry has been successful and the quantity of fertilizer and stock-food peat annually produced is increasing. Large quantities of these products were made in 1918, but the most striking development of the year was the production of more peat fuel in the New England States than has been manufactured commercially in the entire United States in all preceding years. Almost equally striking was the widespread interest manifested in our peat resources which had heretofore been generally regarded as of doubtful value.

Large quantities of peat or sphagnum moss were produced and utilized in this country in 1918 for stable litter, packing material, and surgical dressing, and several hundred thousand acres of peat soils were used for the growth of both general and truck crops. The peat litter was produced by the owners of small bogs for their own use, but the packing material was sold to florists for $25 a ton. According to J. W. Hotson, of the American Red Cross, more than half a million peat moss pads were prepared in this country from October, 1917, to November 11, 1918, by the Northwest and Atlantic divisions of that organization. Most of the moss was gathered by volunteer labor from bogs in Washington, Oregon, and Maine, and the pads were used in American military hospitals, both at home and abroad.

The quantity of crude peat produced in the United States in 1918 was 151,521 short tons. The total number of plants at which peat was commercially produced was 25.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

X-RAY CHEMICAL ANALYSIS.

By A. W. Hull.

THE method of X-ray crystal analysis developed in the Research Laboratory of the General Electric Company just before the war is being further developed, as a method of chemical analysis, which promises to have a very wide and new field of application in that it gives evidence which other methods do not supply, namely, the form of chemical combination of each of the elements present.

The method consists in reducing the substance to be examined to powder form, placing it in a small glass tube, sending a beam of monochromatic X-rays through it, and photographing the diffraction pattern produced. The only apparatus required is a source of voltage, an X-ray tube, and a photographic plate or film. The amount of material necessary for a determination is one cubic millimeter. The method is applicable to all chemical elements and compounds in so far as they are crystalline in form.

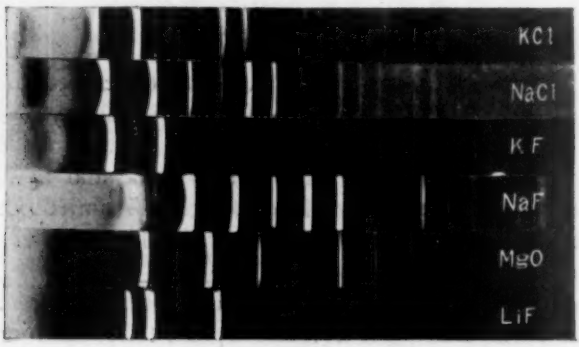
The rays from the X-ray tube pass first through a filter, which absorbs all but a single wave length, then through two slits, which confine them to a narrow beam (about 1 mm. wide); then through the powdered material, which scatters or "reflects" a very small fraction of them; and thence to the centre of the photographic film. An exposure of from one to twenty hours is required, according to the amount of information desired.

When the film is developed it shows, in addition to the overexposed line in the centre, where the direct beam strikes, a series of other lines on each side of the centre. These lines are caused by the "reflections" of the X-rays from the tiny crystals in the powder. Their distance from the centre of the film depends on the distance between the planes of atoms in the crystal, and there is one line for every important set of planes in the crystal. It is evident, therefore, that subsbtances with different crystalline structures will give entirely different patterns of lines. Substances

* Communicated by the Director.

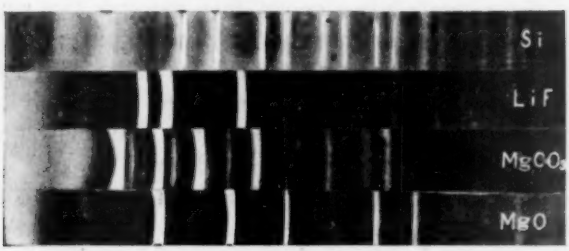
of similar chemical nature and therefore similar crystal structure give similar patterns, but the magnification or spread of the pattern is different for each one, being inversely proportional to the cube root of the molecular volume. Since no two similar sub-

FIG. 1.



stances have *exactly* the same molecular volume it is easy to distinguish them, as the difference is cumulative for lines far from the centre. A further distinguishing mark is the relative intensity of the different lines which differs greatly even in the most closely

FIG. 2.



related compounds, depending on the relative shapes and sizes of the atoms in the compound.

A knowledge of the theory of the production of these lines, and their relation to the crystalline structure of the substance, is not essential to their use for chemical analysis. All that one needs to use in a chemical analysis is the fact that every crystalline substance gives a pattern; that the same substance always gives the

same pattern; that no two different substances give the same pattern; and that in a mixture of substances each produces its pattern independently of the others, so that the photograph obtained with a mixture is the super-imposed sum of the photographs that would be obtained by exposing each of the components separately for the same length of time. This law applies quantitatively to the intensities of the lines, as well as to their positions, so that the method is capable of development as a quantitative analysis.

As illustrations of the general type of photographs obtained with simple compounds and elements, Fig. 1 shows a series of isomorphic alkali halogens, illustrating their similarity of pattern and their differences in spacing and intensity; and Fig. 2 gives a series of dissimilar substances, illustrating their different types of pattern.

Several actual analyses have already been made which will be described in detail elsewhere.[1] It has been found very easy to recognize at a glance each component in a three component mixture and in the case of the simpler salts many more than this could certainly be identified. Accurate quantitative tests have not yet been made, but it is anticipated that an accuracy of one per cent. will be easily obtainable, for components present to the extent of one per cent. or more of the whole sample.

Waste of Chemicals in Pulping Unbarked Wood by the Sulphate Process. ANON. (*Forest Products Laboratory, Madison, Wisconsin, Technical Notes* No. C-5.)—In the manufacture of sulphate and mechanical pulp, all bark must be removed from the wood before chipping or grinding, since any fragment of bark finding its way into the pulp makes its appearance as minute black specks in the finished sheet. For soda or sulphate pulp, the cleaning is often not so thorough, since the alkaline digestion tends to destroy the bark. Some mills bark the wood partly or not at all in the manufacture of sulphate pulp.

To determine the amount of chemical required to pulp unbarked wood, shipments of unbarked shortleaf yellow pine chips and of clear bark were tested by the Forest Products Laboratory of the U. S. Forest Service, at Madison, Wisconsin.

A determination upon a 10-pound sample showed that the unbarked chips contained approximately 96 per cent. wood and 4 per cent. bark, on a bone dry basis. Sulphate pulping trials on clear bark showed that 28.6 pounds of caustic soda and 10.6 pounds of

[1] *J. Am. Chem. Soc.* for June or July.

sodium sulphite were required per 100 pounds of bone dry bark. A yield of 20.9 per cent. of a gelatinous, brownish-black mass, containing pieces of unreduced bark, was obtained. This material could not be screened or washed because it clogged the screen openings. Hand sheets made of it gave physical indications of an extremely hydrated stock, the finished sheets being hard and parchmentized.

The results indicate that in pulping a ton of wood (bone dry), consisting of 96 per cent. wood and 4 per cent. bark, 22.9 pounds of caustic soda and 8.5 pounds of sodium sulphite are needed to reduce the bark. The pulp produced from the bark is useless and, furthermore, produces a variation in color of the pulp, which makes it difficult to mantain a uniform shade in the finished paper.

Experiments With Mixtures of Acetylene and Coal Gas. ANON. (*London Gas Journal,* vol. cxlv, No. 2904, p. 22, January 7, 1919.)—Satisfactory results are said to have attended experiments which have been made in Switzerland with mixtures of acetylene and coal gas; the object being the replacement of the usual mixture of 67 per cent. of oil gas with 33 per cent. of acetylene. It has been found that a mixture of coal gas and acetylene in equal proportions gives the same illuminating power as the oil gas combination. The experiments have further shown that this mixture of gases may be put under a pressure of 9 atmospheres, and heated up to 100° C. without danger.

Gun Powder in Machine Shops. ANON. (*DuPont News Service.*)—A somewhat novel idea is in successful operation in the machine shops of the Delaware and Hudson Railroad Company at Watervliet, N. Y. They are using ordinary black sporting powder to save the time of mechanics for the following operations: Blowing nuts and bolts; breaking up iron and steel to be scrapped; forcing a locomotive piston when rust or corrosion binds it; breaking metal that has become cold in a furnace.

The charge of powder is loaded in steel guns varying in size from end to end from 5 to 12 inches with other dimensions in proportion, and held by a steel plunger, which is forced out when the charge is set off. No wad is used. The plunger is milled to a size to fit the bore of the gun. Some of the gun-barrels are milled in the shape of an octagonal prism, instead of being cylindrical, the bore, of course, in all cases being round. The gun after having been loaded is jacked up with the mouth within about one inch of the object to be struck by the plunger and fired. An average of one ounce of powder is used for each nut or bolt (sizes in common use on locomotives) that is to be broken off or loosened. The load, of course, is varied with the work to be done. By the use of these guns, it is claimed much time and labor can be saved and that a quick blow can be directed at an object that is barely reachable otherwise.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

CHEMICAL ANALYSES OF LOGAN BLACKBERRY (LOGANBERRY) JUICES.[1]

By R. S. Hollingshead.

[ABSTRACT.]

THE Bureau of Chemistry recently completed an investigation, undertaken to establish methods for the detection of dilution common in commercial products made from the Logan blackberry, and to set analytical standards for them. Logan blackberry juice has become very popuplar as a beverage, and the berry is used also in making jams, jellies, and soda-fountain sirups. The juice is naturally so sour that when it is to be used as a beverage it must be diluted, from 2 to 3 parts of water being the usual proportion, and sweetened with sugar, about 1 part. As a rule, sirups for the soda-fountain are prepared by adding sugar to the undiluted juices, in the proportion of from about 1 part of juice to 1 part of sugar to, roughly, 3 parts of juice to 1 of sugar.

Many samples of the pure expressed juice and of the commercial product made from berries grown in Washington and Oregon were analyzed by the Bureau in 1916, while in 1917 a large number of samples made from California berries were examined.

The juices from the fruit grown in Washington and Oregon were found to differ markedly in composition from those which came from the California berries. A large variation was also noted in the composition of juices from fruit grown in the different parts of these States, due probably to the difference in rainfall. Apparently California juices have a somewhat higher ash content and lower acid content than those from the more northern States.

It would seem impossible to determine exactly the amount of water which has been added to commercial Logan blackberry juices. Its presence can, however, be detected, and the amount roughly approximated. The following table gives the tentative limits suggested for the most significant determinations on Logan blackberry products.

* Communicated by the Chief of the Bureau.

[1] Department of Agriculture Bulletin 773, issued May 29, 1919.

Tentative Limits for Logan Blackberry Juices.

Source	Non-sugar solids		Ash		Acids, as citric	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Washington and Oregon	3.92	2.80	0.43	0.25	2.33	1.42
California	3.74	3.06	.63	.43	1.96	1.06

AN AËROBIC, SPORE-FORMING BACILLUS IN CANNED SALMON.[2]

By Albert C. Hunter and Charles Thom.

[ABSTRACT.]

BACTERIOLOGICAL examination of 530 cans of salmon, representing 9 different brands, showed 237 unsterile cans, 224 of which contained a particular organism of the mesentericus group, either in pure culture or mixed with other species. Only 13 of the cans showed active spoilage.

The organism is an obligate aërobic spore-former, Gram positive, and motile. It produces a dark-red ring about a centimeter below the colony in carbohydrate media and causes rapid decomposition in fish.

No relation exists between the presence of bacteria of this type and the quality of the food when the can is opened. The fish in many cans containing the organisms appeared to be perfectly fresh and sound, while in some sterile cans the fish was obviously decomposed.

A bacteriological test for sterility in canned food may show viable organisms without demonstrating spoilage. The purpose of canning is accomplished if the food is preserved but the finding of viable organisms calls for close scrutiny both of the material and of the canning method used.

ZINC IN OYSTERS.[3]

By R. S. Hiltner and H. J. Wichmann.

[ABSTRACT.]

IN 1915 notable amounts of zinc in oysters were found almost simultaneously in two of the laboratories of the Bureau of Chemistry, each working independently of the other and on quite dif-

[2] *J. Ind. Eng. Chem.*, Vol. xi, No. 7 (July, 1919).

[3] *J. Biol. Chem.*, vol. xxxviii, No. 2 (June, 1919).

ferent problems. The Bureau, therefore, undertook an investigation of the occurrence of zinc and also of copper in oysters from various localities on the Atlantic seaboard. The relation of the zinc content of the water in which the oysters grew to that of the oysters, and the ratio of zinc to copper in oysters, were studied also.

The results of this investigation indicated that zinc is universally present in oysters, at least in those grown in Atlantic waters, and that it is probably always associated with copper. It was also evident that no direct relation exists between the zinc content and the body weight of the oysters, no uniformity in the ratio of zinc to copper, and no correlation between the zinc content of the oysters and that of the water in which they grow. The average zinc content of 60 samples of oysters analyzed was found to be 457 milligrams per kilogram, the values ranging from 26 to 1300. The quantities of copper found in 29 samples ran from 12 to 362, with an average of 80 milligrams per kilogram. The greater amounts were found in water contaminated by metallurgical and factory wastes. Vegetation and organic matter dredged up with the oysters in one locality contained notable quantities of zinc, and in some instances traces of copper.

COMMERCIAL PRESERVATION OF EGGS BY COLD STORAGE.[4]

By M. K. Jenkins.

[ABSTRACT.]

AN extensive investigation on the preservation of eggs by cold storage was conducted during the seasons of 1914, 1915, and 1916. The contents of 841 cases were examined on going in and again on coming out of storage. That is, approximately 26,000 eggs were examined individually, each egg being candled twice. Most of the eggs used in the observations recorded were purchased in the Corn Belt States of the Middle West, and were shipped east in refrigerator cars, being from 3 to 7 days *en route*. As soon as received they were transferred to a commission house equipped with chill rooms, a candling and a breaking room, all of which were refrigerated. Here numerous observations were made of the eggs before being stored and at various intervals during the storage period.

[4] U. S. Department of Agriculture Bulletin 775, issued June 3, 1919.

Candling proved to be a much more accurate method for the selection of eggs than inspection or clicking.

Freshly laid eggs, with clean whole shells that had not been wet, showed a negligible loss in bad eggs, even after they had been stored 10 or 11 months.

The rate of evaporation of moisture from eggs was remarkably uniform during the storage period, and averaged from 3 to 4 ounces per case per month in the storage rooms under observation. This moisture was condensed on the brine pipes and absorbed by the air, the case and the fillers. Most of the absorption of moisture by the egg packages occurred during the first few months in storage. A gradual rise in the humidity of the cold storage room was noted with the advance of the season.

Eggs which were fresh when stored showed, after being held some time, an increased air space, and often a tinge of yellow in the white. Although the yolk membrane became slightly weakened, commercial separation into white and yolk usually was easily accomplished, even after eleven months' storage. The percentage of ammoniacal nitrogen in eggs increased during storage, the rise being greatest during the early part of the storage period.

While held commercially in cold storage eggs develop a characteristic "cold storage" taste, which usually can be detected about the seventh month in storage, and grows stronger the longer the eggs are held thereafter. This flavor probably is due to the absorption of the odors from the surroundings, particularly the strawboard fillers in which the eggs are packed.

Hydroelectric Power for West Coast of Africa. ANON. (*Electrical Review*, vol. lxxiv, No. 24, p. 981, June 14, 1919.)—A hydroelectric plant is being built by the Bauchi Tin Mines, Northern Nigeria, which will be used to operate the tin mines. This hydroelectric development will have an initial capacity of 1500 horse power, which will be transmitted 12 miles to the mines. The cost of the installation will be in the neighborhood of $400,000. It is estimated that the cost of energy will be about 1.2 cents per kilowatt-hour as compared to 5.2 cents for energy generated from coal or oil. The annual saving which it is estimated will result from this change is $195,000.

NOTES FROM THE U. S. BUREAU OF MINES.*

MOTOR GASOLINE; PROPERTIES, LABORATORY METHODS OF TESTING, AND PRACTICAL SPECIFICATIONS.[1]

By E. W. Dean.

GASOLINE as bought on the market may be the product of ordinary refinery distillation, it may be casing-head gasoline blended with heavy naphtha, or it may be the product of a cracking process. These three may be blended with each other in varying proportions. The volatility desirable depends on the service required and on the vaporizing power of the engine. In general, there should be enough loco-boiling constituents to permit the ready starting of a cold motor and not enough to make the gasoline dangerous and subject to high evaporation losses. Within the capacity of the engine to utilize them efficiently the heavier and less volatile fractions have a greater horsepower per gallon. Proposed specifications for gasoline are given, analytical methods and equipment used in connection with them are described.

TRAPS FOR SAVING GAS AT OIL WELLS.[2]

By W. R. Hamilton.

AN oil well that does not produce appreciable quantities of gas along with the oil, especially during its early life, is an exception. When wells flow freely into the air a serious loss of oil results. The loss is from two causes: (1) The sudden release of pressure which allows the gas to escape and carry with it quantities of oil which are held in suspension; and (2) the evaporation caused by the spray of oil. The loss from evaporation alone in a wildly flowing well producing oil of Cushing grade, will probably exceed 25 per cent. during the time of expulsion. This does not cover losses in handling and storage. The gas is of course wasted. Not only do the so-called dry gases escape, but they carry away much of the lighter oil fractions as vapor, so that the escaping gas is often highly saturated with gasoline, causing a heavy loss.

* Communicated by the Director.

[1] Technical Paper No. 214.

[2] Technical Paper 209.

Gasoline traps are simple in construction. The mixture of oil and gas is allowed to flow through a chamber large enough to reduce the velocity of the mixture to the point where the oil and gas tend to separate. The gas is drawn off from the oil at the top of the chamber. The oil is drawn off at a point below the level of the liquid so that the escape of gas through the discharge opening is prevented. In this way all the gas is saved and its gasoline content may be recovered and the evaporation of the oil is prevented. In addition, the danger of the well catching fire is greatly reduced. Different designs of traps are described, some one of which will be suited to the conditions existing in any given well. The small cost of a trap and the large savings which result from its use make it desirable that they should be used in all cases. It would, in fact, be desirable that their use should be made compulsory by State legislation.

LIGNITE: ITS CHARACTERISTICS AND UTILIZATION.[3]

By S. M. Darling.

ONE-THIRD of the known coal resources of the United States consists of lignite, which is little used because it normally contains 35–30 per cent. of water as mined, but loses it by evaporation on exposure, with the result that it crumbles into fine pieces during shipment. The freight rate on the contained water is also important. As a result 2,000,000 tons of bituminous coal, hauled on the average 1000 miles, is shipped annually into territory tributary to the North Dakota lignites that could be supplied with lignite with an average haul of 400 miles; saving annually the travel for 600 miles of 50,000 coal cars and 1200 engines and train crews. The same general condition obtains in the territory tributary to the Texas lignites. Dried lignite may be used on automatic stokers, pulverized lignite may be used in that form, dried lignite briquettes may be used in hand-fired furnaces, carbonized lignite may be used in suction power-gas producers, and carbonized lignite briquettes may be used for industrial heating. Raw lignite used in by-product gas producers yields 60,000 to 70,000 cubic feet of gas of 140 B. T. U. per cubic foot; 70 to 80 pounds of sulphate of ammonia, and some tar, of undetermined value. The experiments so far conducted open wide economic and commercial possi-

[3] Technical Paper 178.

bilities, and it is believed that the broader and more thorough investigation made possible by the recent appropriation of $100,000 for investigation by the Bureau of Mines will point the way to the establishment of carbonizing and briquette plants throughout the lignite-bearing regions of the country. The present yearly production of coal amounts to 0.017 per cent. of the known minable coal resources of the country. C. P. Steinmetz is authority for the statement that the possible hydro-electric power that could be developed if every drop of water in the whole United States could be used would not supply an equal amount of power. It is evident, therefore, that the efficient utilization of our lignite resources is a problem of the first magnitude.

MINOR NOTES.

T. N. T.—An investigation of the hygroscopicity of T. N. T., recently completed at the Pittsburgh Station of the Bureau of Mines, shows that it is no greater than that of an empty crucible or one filled with powdered glass; that the moisture absorbed in a saturated atmosphere is merely that due to the usual moisture deposited on non-hygroscopic substances under these conditions. The detailed results of this study will soon be published.

Waste Products of Kaolin.—It has been found by the Columbus Station of the Bureau that the waste products from the refining of kaolins can be used in some cases for the making of high-grade silica fire-brick. Where the brick are highly colored with iron, a 2 per cent. solution of $CaCl_2$ is used and the chlorine liberated removes most of the iron by volatilization. Dolomite brick were successfully made by mixing 12 per cent. coal tar with dead-burned dolomite, pressing at 1000 pound per square inch and burning to cone 20. In order to make brick more resistant to slaking, dipping in dehydrated tar was found to give the best results.

Photometer.—The construction of a photometer to measure the intensity of luminosity of dials or other surfaces covered with radium luminous material has been completed at the Golden, Colorado, station.

Geophone.—In a recent test with the geophone at coal mines in Pennsylvania, pounding with a sledge in the rib of a mine was detected through a cover of 525 feet.

Volatilization Plant.—The new volatilization plant at the Salt Lake City Station of the Bureau consists of a rotary kiln with a

capacity of 300 pounds ore per hour and a Cottrell precipitation plant with a capacity of 3000 cubic feet of gas per minute. The kiln has a length of 20 feet and is heated with a high-pressure burner, burning gas oil of 25° B., and is driven by an electric motor so arranged that the speed of rotation may be varied. The Cottrell precipitator consists of two units of twenty 6-inch pipes each. It is operated by a Thoradson 5 KVa. 80,000-volt precipitator transformer and a Western Precipitation Company rectifier. The regulation of the primary voltage of the transformer is obtained by an auto transformer and a theatre dimmer.

Mine Fires.—At the mine of the Princeton Coal Company, Indiana, an area which had been sealed off to extinguish a fire was recovered with the coöperation of the Bureau engineers, at the end of April.

Alaska Power Development.—A study of the possibilities of power development in the interior of Alaska has been made by the Fairbanks Station, which indicates that the present demand for coal for domestic heating, steaming purposes, and for electric power for placer and lode mining and domestic use would justify the erection of a plant to utilize the Nenana lignite. A carbonization plant would furnish the solid fuel required and yield enough gas to generate part of the power required. The remainder would be generated by a steam plant burning carbonized or dead lignite. To the present time the demand for fuel has been met with wood, but the growing scarcity and increasing cost of it make it essential that some other form of power supply be made available, otherwise the mining and other industries of the region will inevitably suffer a progressive decline.

Silver Chloride.—An investigation of the vapor pressure of silver chloride is in progress at the Berkley station of the Bureau. The method is not yet sufficiently standardized to yield thoroughly reliable results, but the work so far indicates that the vapor pressure of silver chloride is less than 5 mm. at 1000° C. and in the vicinity of 15 mm. at 1150° C. It is therefore much less volatile than lead chloride.

Mine Gases.—An extensive series of gas samples were taken at the recent fire in the Argonaut Mine, California, and it was found that the systematic analysis of gases from the main ventilation shaft served as a reliable index of conditions in the fire zone.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, June 4, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 4, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for final action:

No. 2729: Simplex Fluid Meter. A quorum not being present, final action was deferred.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, June 11, 1919.)

RESIDENT.

MR. WALTER B. MURPHY, Manufacturing Manager, The Barrett Company, Chemical Department, Frankford, Philadelphia, Pennsylvania.

NON-RESIDENT.

DR. E. A. ECKHARDT, Physicist, Bureau of Standards, Washington, District of Columbia.

MR. FRANCIS P. FLEMING, Attorney-at-Law, Heard Building, Jacksonville, Florida.

CHANGES OF ADDRESS.

MR. G. EDWARD BARNHART, 318 Mills Avenue, Akron, Ohio.

MR. WILLIAM E. BULLOCK, 29 West 39th Street, New York City, New York.

MR. THOMAS L. BURTON, Westinghouse Air Brake Company, 165 Broadway, New York City, New York.

MR. EDWIN M. CHANCE, 611 Chestnut Street, Philadelphia, Pennsylvania.

MR. FRANK H. CLARK, 15 Park Row, New York City, New York.

LIEUTENANT COLONEL GEORGE S. CRAMPTON, M. C., U. S. A., Office of the Surgeon, District of Paris, No. 7, Rue Tilsitt, Paris, France.

MR. J. H. GRANBERY, care of Morgan, Harjes & Company, 14 Place Vendome, Paris, France.

MR. WILLIAM A. HAINES, 6445 Wissahickon Avenue, Philadelphia, Pennsylvania.

MR. H. A. HORNOR, Minerva P. O., Essex County, New York.

MISS EMILY E. HOWSON, Glen Moore, Chester County, Pennsylvania.

MR. EDWIN F. KINGSBURY, Eastman Kodak Company, Rochester, New York.

MR. CLINTON N. LAIRD, Canton Christian College, Canton, China.

DR. HUGO LIEBER, 23 East 26th Street, New York City, New York.

MR. J. MILLIKEN, Union Arcade Building, Pittsburgh, Pennsylvania.

MR. HUGH RODMAN, Rodman Chemical Company, Verona, Pennsylvania.
MR. JAMES G. VAIL, Philadelphia Quartz Company, 121 South 3d Street, Philadelphia, Pennsylvania.
MR. FRANCIS RALSTON WELCH, Devon, Pennsylvania.
MR. ALAN WOOD, 3d, Flat Rock, North Carolina.
MAJOR ARTHUR W. YALE, 1947 Linwood Avenue, San Diego, California.

NECROLOGY.

Mr. C. W. Allen, 523 Oley Street, Reading, Pennsylvania.
Mr. Charles O. Baird, 207 Crozer Building, Philadelphia, Pennsylvania.
Miss Harriet Blanchard, 1511 Walnut Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

CARNEGIE, DAVID, and GLADWYN, S. C.—Liquid Steel, Its Manufacture and Cost. 1918.
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HARGER, W. G., and BONNEY, E. A.—Handbook for Highway Engineers. 1919.
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GIFTS.

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Camden Forge Company, Catalog of Forgings. Camden, N. J., 1919. (From the Company.)

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Hollands Manufacturing Company, Catalog No. 24. Erie, Pa., no date. (From the Company.)

Illinois Steel Company, Catalog of Track Materials. Chicago, Ill., 1919. (From the Company.)

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Yale and Towne Manufacturing Company, Semi-Centennial Souvenir. New York, N. Y., 1918. (From the Company.)

CORRESPONDENCE.

Cable Address "Edison, New York"

FROM THE LABORATORY OF THOMAS A. EDISON.

ORANGE, N. J. April 19, 1919.

Mr. R. B. Owens, Secretary,
The Franklin Institute,
Philadelphia, Penna.

DEAR SIR:

I thank you for your letter of April 17th, and wish to express my sincere appreciation of the honour conferred upon me by The Franklin Institute in electing me an Honorary Member of the Institute.

Yours very truly,
(Signed) THOS. A. EDISON.

A/6969.

WAR DEPARTMENT
OFFICE OF THE CHIEF SIGNAL OFFICER

WASHINGTON, April 23, 1919.

Major R. B. Owens,
Secretary, The Franklin Institute,
Philadelphia, Pa.

SIR:

I have the honour to acknowledge receipt of your communication of April 17, 1919, informing me that at a Stated Meeting of the Institute held on the evening of Wednesday, April 16, 1919, I was unanimously elected an Honorary Member of The Franklin Institute.

I beg to express to the Institute, through you, my sincere appreciation of its action in thus electing me an Honorary Member of the oldest scientific institution in America, one which has through all the years exerted a powerful influence in the advancement of Science and the Mechanic Arts.

Faithfully yours,
(Signed) GEORGE O. SQUIER.
Major General
Chief Signal Officer of the Army.

WOLCOTT GIBBS MEMORIAL LABORATORY, HARVARD UNIVERSITY.

CAMBRIDGE, MASSACHUSETTS, U. S. A., April 24, 1919.

THEODORE WILLIAM RICHARDS, *Director.*

Dr. R. B. Owens,
Secretary,
The Franklin Institute of Pennsylvania.

SIR:

Your letter of April 17th honours me very greatly. I beg that you will communicate to the Members of the Institute my heartfelt appreciation of the high distinction conferred upon me by election to honorary membership. It is an especial pleasure and satisfaction that the eminent men of my native State and City should thus welcome me to their fellowship; and I shall always be proud indeed to have my name entered on the rolls of the famous Institute.

I beg to remain, with assurances of highest regard

Respectfully yours.

(Signed) THEODORE W. RICHARDS.

HENRY C. FRICK EDUCATIONAL COMMISSION.
1954 Perrysville Avenue.

JOHN A. BRASHEAR, *President.*

PITTSBURGH, Pa., May 16, 1919.

MY DEAR DR. OWENS,

You don't know how proud I am of the beautiful diploma of Honorary Membership of The Franklin Institute. There are eleven diplomas hanging on the walls of my work room and all so nice and fully appreciated, but the Franklin is the prettiest of all.

Then an old fellow like me prizes the names on his diplomas—especially if they happen to be his friends—and all the names are friends of Uncle John. I confess that I am in love with this diploma and the honor you have conferred upon me. The good Lord knows the element of self conceit has never tainted the life of your friend—but when I unrolled the diploma—or rather had my granddaughter do it for me, I felt just a pardonable pride! So don't scold me for this little weakness, for though nearly 79, I am not in my dotage yet. A fellow working 12 to 14 hours a day trying to send a little sunlight out into the world to make or help make the shadowed pathways of his fellow travellers a little brighter should not be accused of dotage, should he?

How I would love to be with you on the 21st. Sir James Dewar has been a personal friend for 27 years and General Squier a man for whom we have done some of our best work. I fear I cannot get away.

Thanking you dear Dr. Owens and all your colleagues, I am,

Cordially yours,

(Signed) JOHN A. BRASHEAR.

PROF. DR. H. KAMERLINGH ONNES.

LEIDEN, 24 May, 1919.
HUIZE TER WETERING
HAAGWEG.

SIR:

I beg to express my sincere gratitude for the honour The Franklin Institute has bestowed on me by electing me unanimously as an Honorary Member. The appreciation in this way of my work by The Franklin Institute who did me the honour to award one of the first Franklin Medals to me, makes a deep impression on me. I cannot thank The Franklin Institute enough for the continued encouragement given to me, but I can assure The Franklin Institute that this encouragement is of the greatest value for me now I am restarting my researches which have suffered very much from the general circumstances as well as from a long illness.

I am respectfully,
(Signed) H. KAMERLINGH ONNES.

DR. R. B. OWENS, *Secretary of The Franklin Institute of the State of Pennsylvania, Philadelphia.*

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31 Via Garibaldi, Gianicolo,
ROME, May 30th, 1919.

R. B. Owens, Esq.,
Secretary of
The Franklin Institute,
Philadelphia, Pa.

SIR,

Having been away from Italy for some time I have only just received your letter of April 17 in which you inform me that at a Stated Meeting of the Institute held on April 16 of this year I was elected Honorary Member.

I take great pleasure in accepting this Honorary Membership of The Franklin Institute, and shall feel obliged if you will convey to the Governors of the Institute my deep appreciation of the honor which they have conferred upon me.

I am,
Respectfully,
(Signed) G. MARCONI.

HAARLEM, June 8, 1919.

GENTLEMEN:

Allow me to express my most hearty thanks for the honour you have bestowed upon me by electing me an honorary member. I appreciate very much this new token of the good will with which you have judged my work, and I consider the membership of your celebrated and time-honoured Institute as one of the very best rewards that can be given to a scientific man.

With high regards, I have the honour to be, gentlemen,
Your obedient servant,
(Signed) H. A. LORENTZ.

TO THE MEMBERS OF
THE FRANKLIN INSTITUTE.

PUBLICATIONS RECEIVED.

The Blind, Their Condition and the Work Being Done for Them in the United States, by Harry Best, Ph.D. 763 pages, 12mo. New York. The Macmillan Company, 1919. Price, $4.

U. S. War Department, Annual Reports 1918: 3 vols., illustrations, plates, maps, diagrams, 8vo. Washington, Government Printing Office, 1919.

U. S. Bureau of Standards: Circular No. 76. Aluminum and Its Light Alloys. 120 pages, illustrations, 8vo. Washington, Government Printing Office. Price, 20 cents.

U. S. Coast and Geodetic Survey: Terrestrial Magnetism. Results of Magnetic Observations Made by the United States Coast and Geodetic Survey in 1918, by Daniel L. Hazard, Chief, Division of Terrestrial Magnetism. 32 pages, 8vo. Washington, Government Printing Office, 1919.

A Proposed "Poison-Gas."—The signing of the armistice brought suddenly to a close several terrible methods of offense that were just about ready to be employed by the allied and associated powers. These methods have been more or less made known to the public, and among them is an asphyxiating gas which promised to be a valuable one for war purposes, and for which American chemists had just about succeeded in perfecting the procedure for mass manufacture when hostilities were suspended. The account of the method of manufacture was given a short time ago in the *Journal of Industrial and Engineering Chemistry*. The substance is methyldichlorarsin, CH_3AsCl_2. The process of manufacture is quite elaborate, and, as far as the experiments went, the cost of the pure product was about $2.50 per pound. The operation did not reach the extended development that was attained by mustard gas or phosgene, but was still within what was termed the "Small-scale Manufacturing Section of the C. W. S.," when Messrs. Uhlinger, Clapp and Cook, who furnish the account from which this note is quoted, were released from duty in the matter.

The properties of the substance are not given, but from its close relation to the kakodyl series it is not difficult to guess at its general nature as an asphyxiator. H. L.

Coal Production in Germany. ANON. (*Power*, vol. xlix, No. 25, p. 998, June 24, 1919.)—The German War Commissary states that Germany's coal production is decreasing in all districts, because the pay is no longer based on the work done but has a minimum of 16 to 18 marks ($3.81 to $4.28, at normal exchange) per day. The present coal production in the Ruhr district is 9000 to 10,000 tons per day, compared with 34,000 tons in peace times and 24,000 tons during the war. In upper Silesia the daily output has been reduced to 2000 carloads, compared with 14,000 in peace times and 11,000 during the war.

CURRENT TOPICS.

Mapping from the Air. ANON. (*U. S. Geological Survey Press Bulletin*, No. 410, June, 1919.)—Requests made to the United States Geological Survey, Department of the Interior, for information concerning the possibilities of photographic surveying from airplanes or other aircraft have recently become so numerous that it is deemed necessary to issue a statement on this subject. For two years the United States Geological Survey, which prepares and publishes more maps than any other organization in the world, has devoted much time and labor to the study of problems to be solved in photo-aerial surveying. The camera has long been used in surveys on the ground, and the Geological Survey has been making studies to determine the best methods of using it in aerial work. Before the war the panoramic camera was employed by the Geological Survey for mapping in Alaska, and it has been widely used for photographic surveying in Canada and in Europe. Aerial photographic surveying involves no new principles, yet it differs essentially from photographic surveying on the ground, for the line of view from a camera in a balloon or an airplane is vertical, not horizontal. A complete statement of the Geological Survey's investigations in photographic mapping from the air will later be prepared for publication.

The principal object in an aerial survey is to obtain on a horizontal plate or film a picture of the area below the camera. If the area is itself a plane the picture of it taken from an airplane on such a plate is a true map, but no apparatus has yet been devised that will maintain the plate in a truly horizontal position when the airplane is in motion; and as the earth's surface is almost nowhere plane the photograph must be corrected to obtain a map free from distortion. The nearest approach to an aerial map so far made is the so-called "mosaic map," which is really not a map at all but merely a patchwork of photographs. The pictures composing such a mosaic show distortions, due partly to the deviation of the plate from the horizontal position and partly to relief in the surface photographed, and these distortions render the picture useless for accurate map construction. Distorted photographs of an area that has been previously mapped can be laid down over a network of points whose positions are known, and by distributing the errors due to distortion a mosaic may be constructed that will present a good appearance. For correcting and revising older maps by the addition of culture, timber areas, new roads, and similar features, such mosaics have a distinct value, but they are worth little as material for use in constructing new maps.

It may be said that photographic mapping from aircraft is entirely practicable but that it has not yet been brought to the point where it can supersede ground surveying. The science of cartography will no doubt be greatly advanced when the aerial method is perfected, but fundamental problems remain to be solved, and this fact should be recognized and all possible energy should be devoted to the solution of those problems. It is hoped that solutions of the essential problems in photo-aerial surveying will soon be obtained, and that this method will be put to practical use in map-making.

New Chemical Journals and a New Method in Chemical Journalism. H. LEFFMANN. (*The Catalyst*, vol. iv, No. 5, May, 1919.)—Early in the year 1918 the Swiss Chemical Society decided to begin the issue of a journal to appear from six to eight times a year, and contain brief notes and formal memoirs in the three languages (French, Italian and German) used in the country. By this means the Society hopes to give to the world a synopsis of the labors of Swiss chemists. The preface of the first number is dated at Geneva, April 25, 1918. The rivalry of the three languages, of course, increased in bitterness by the events of the last four years, has been deftly avoided by the founders of the journal by putting the title in Latin, *Helvetica Chemica Acta*. The first number is standard octavo size, containing ninety-five pages of original matter, well printed on good paper. The prospectus is given in the three languages, but the preface is in French. Of the seven contributions, four are in German and three in French. They cover both pure and applied chemistry. Among the latter is a notable one on the occurrence of hydrogen selenid in rainwater and melted snow. Several issues have appeared, and the amount and quality of the contents have maintained the standard of the initial number.

The other newcomer is from France. It is the official journal of the newly-formed French society of industrial chemistry. The first number of the journal (*Chimie et Industrie*) is dated June 1, 1918, and it has been continued since as a monthly. It contains about one hundred pages well printed on good paper of about the area of the J. I. E. C. The matter of the journal is of very good quality, and covers the usual variety of original papers and abstracts of current literature, but a special feature deserves some notice. Each number contains a section on "Economic Organization," in which questions of education, teaching, professional apprenticeship, industrial hygiene, protection of childhood, anti-alcoholic and antituberculosis crusades can be treated with a breadth of view and interest that they deserve. This indicates a broader scope than is usual in chemical journals, and affords an inkling of the deep impression that socialism has made upon the educated classes of France, especially in professional circles.

Science and Industry. (*Machinery*, London, vol. xiv, No. 350, p. 321, June 12, 1919.)—A new viewpoint manifests itself in the interminable controversy upon the application of science to industry, with which is bound up the place that theoretical training must take in engineering education. The whole history of the conflict of opinion among educationalists and industrialists is that the former has continually and dogmatically laid it down that the practical man in the past has had little understanding of the value of science and has therefore failed to appreciate the place which it should play in industrial life. Generally speaking, the so-called practical man has accepted the doctrine that science and theoretical training must take a more prominent place, and he has left it largely to the educationalist to define that place. A change, however, appears to be coming over the attitude of the practical, or, shall we say, the business man, in this respect. The point of view is that whilst professors and teachers wish the industrial employer to have a greater faith in science, have they themselves as much enthusiasm and faith—and, be it added, knowledge of practical conditions—in industry? In other words, have the teachers the practical knowledge which enables them to teach science in such a way that it can be applied to the best advantage in industry? Hitherto our universities and technical colleges have placed rather too narrow a limit upon the meaning of science; there is something more than a science of things which needs to be taught those who are to take the leading places in industry, and it has been well pointed out that there are such things as the science of management—the application of psychology in management—the training of staff and the direction of salesmanship to which at present our universities and colleges are paying very little attention. We believe that the only organized effort of this nature is being made at the Manchester University, but this aspect of the application of science in education and in industry must play a larger part in the minds of those from whom we are expected to take the law as regards education. That can only come about through the medium of a greater practical knowledge on the part of the teachers. This, perhaps, raises important questions as to whether the remuneration offered to those who are expected to teach our young men is sufficient to attract the right kind of men. Anyway, experience has shown that the average man engaged in industry has not the time, and often not the ability, to undertake teaching. Therefore we shall have to continue to rely mainly upon theoretically trained men for the purpose, but steps must be taken to keep such men in close contact with the needs of industry before we can expect our university and college curricula to fit those needs.

Moving Pictures in Science. (*Engineering News-Record,* vol. lxxxii, No. 26, p. 1239, June 26, 1919.)—Motion-picture houses for some time have been showing pictures of what they call the " analysis of motion," in which well-known actions, such as figure skating, sprinting and baseball pitching, are reproduced on the screen at one-eighth the actual speed of the performer. Every element of motion in these pictures stands out with snapshot clearness. Grace hitherto unsuspected is revealed, and the methods by which results are achieved are understood as never before. This latter phase has decidedly an engineering application in the development of motion study and its consequent readjustment of production methods. No false or unnecessary movement can escape detection, but at the same time the sense of motion, lacking in a series of snapshots, is always present. An analogy may be found in the system used by Nathan C. Johnson in studying the setting of concrete. While the popular motion picture film slows down normally fast processes, Mr. Johnson's automatic camera speeds up the normally slow, so that one can, for instance, observe in a few minutes the physical and chemical phenomena of many days. Motion pictures have already had a marked influence on social conditions; may they not have a bright future in science?

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